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PREFACE

This is the 13th Secretary's Annual Report to Congress of the United States Department of Energy, and it covers the years 1992 and 1993. Activities of all elements of the Department are described herein except those of the independent Federal Energy Regulatory Commission, which issues its own report.

All years recorded in this report are fiscal years unless otherwise noted.

In accordance with section 3 of the Metric Conversion Act of 1975 (Public Law 94-168) as amended by the

Omnibus Trade and Competitiveness Act of 1988 (Public Law 100-418), metric equivalents have been included in parentheses for each measurement. In converting crude oil, with its varying densities, from barrels to metric tons, the editors used the Energy Information Administration's preferred conversion factor of 7.32 barrels per metric ton at a specific gravity of 0.86.

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CHAPTER 1

ENERGY EFFICIENCY

INTRODUCTION

The years 1992 and 1993 presented many opportunities for programs in energy efficiency. The two events that largely shaped developments were the passage of the Energy Policy Act of 1992 (EPACT) and the announcement of President Clinton's Global Climate Change Action Plan (CCAP) in 1993. Both EPACT and CCAP require accelerated and widespread adoption of renewable energy and energy efficiency technologies, which are fundamental to achieving the Clinton Administration's economic and environmental goals. Benefits include pollution abatement, reduced global warming, enhanced energy security, improved trade balances, job creation, and improved productivity and competitiveness for U.S. industry.

EPACT, which was signed into law in October 1992, is the most significant and comprehensive set of legislative changes to U.S. energy policy in more than a decade. Energy efficiency and renewable energy are at the heart of EPACT; and the Office of Energy Efficiency and Renewable Energy is responsible for addressing 19 of the act's 30 titles. EPACT reauthorized a majority of Energy Efficiency's existing programs and expanded its role in commercialization and rulemaking. The act affects all four market sectors in the office—utilities, transportation, industry, and buildings—and the Office of Technical and Financial Assistance. The office must implement more than 270 specific actions, more than 150 of which will be completed during 1994. The act gives Energy Efficiency a more proactive role: The office will involve a broad range of public and private interests (stakeholders), accelerate the rate at which energy efficiency and renewable energy technologies are researched and commercialized, and help make

the Federal sector an example to the Nation in adopting energy efficiency and renewable energy technologies and in purchasing or leasing alternative-fuel vehicles.

Many of EPACT's provisions extend into the next century, with tremendous rollover effects. Implementing EPACT should create jobs and significantly reduce energy consumption and oil imports.

Energy Efficiency's programs are affected by the following EPACT provisions:

1. Research and development and infrastructure development of electric, biofuel, and hybrid vehicles
2. Alternative-fuel-fleet-requirements vehicles
3. Building energy efficiency standards for residential, commercial, and industrial buildings and new equipment standards and labeling
4. Federal energy management
5. Process-oriented industrial energy efficiency
6. Advanced heating and cooling technologies for natural gas

Because it is aligned with the market (end-use) sectors of the economy—utilities, transportation, industry, and buildings—Energy Efficiency is ideally organized to accomplish its mission. This sector alignment is critical to applying the energy efficiency technologies that will secure U.S. energy needs, increase technology transfer and overall economic competitiveness, and improve environmental quality.

Toward these ends, Energy Efficiency has implemented a twofold strategy: It will advance technology through research, development, and demonstration, in close collaboration with the private sector. And it will foster the adoption of cost-effective technologies and practices by

reducing regulatory market barriers, seeking voluntary commitments to improve energy efficiency in all sectors, and, in some areas, establishing cost-effective efficiency standards for key energy-using equipment. The projected energy savings accruing from this strategy and cited in this chapter are expressed in terms of primary energy. Energy Efficiency's 1993 budget (Table 1-1) reflects the Department's commitment to energy efficiency and renewable energy programs.

The Office of Energy Efficiency and Renewable Energy meets the requirements of EPACT through five offices: the Offices of Utility Technologies, Transportation Technologies, Industrial Technologies, Building Technologies, and Technical and Financial Assistance. A brief description of the mission and 1992-1993 accomplishments of each follows:

1. In 1992 and 1993, the Office of Utility Technologies continued to encourage utilities to use integrated resource planning (IRP). At present, IRP is required or soon may be for electric utilities in 31 states and for gas utilities in 25 states. The Department continued to work closely with states, electric and gas utilities, consumers, interest groups, power marketing administrations, and Federal agencies to support them in their IRP efforts, including many mandated by EPACT. The office's programs in energy management included expanded cooperative efforts to improve the efficiency of electric power transmission and distribution systems. In accordance with EPACT, the office also supported expanded research on the possible health effects of exposure to electric and magnetic fields, on devices that use high-temperature superconductivity, and on the production and storage of hydrogen.
2. In 1992 and 1993, the Office of Transportation Technologies continued to support energy efficiency through research and development on light-duty electric vehicles and advanced alternative-fuel turbine and diesel engines. The office also conducted research and development on fuel cells, other propulsion systems, and materials technology, including advanced ceramic materials that permit engines to operate at higher temperatures and thus more efficiently. In cooperation with other Federal agencies, DOE also spearheaded the purchase of alternative-fuel vehicles for the Federal fleet.
3. In 1993 the Office of Industrial Technologies continued to collaborate with industry to develop industrial technologies that reduce energy and material waste, enhance fuel flexibility, increase productiv-

Table 1-1—1993 Office of Energy Efficiency and Renewable Energy budget structure by program category

Program	Appropriation
	(thousands of dollars)
Solar Energy	181,569
Supply	155,043
Demand	8,200
Waste and Detoxification	2,889
Technical Assistance and Deployment	7,942
National Renewable Energy Laboratory	6,555
Other	940
Geothermal Systems—Utility Sector, Supply	22,664
Hydropower—Utility Sector, Supply	1,043
Electric Energy Systems, Demand	31,206
Energy Storage Systems, Demand	9,972
Policy and Management—Energy Supply	
Research and Development, Other	2,859
Geothermal Resource Development Fund,	
Other	0
Buildings Sector, Demand	52,261
Industry Sector	111,701
Supply	12,882
Demand	80,090
Waste	18,729
Transportation Sector	138,383
Supply	32,143
Demand	106,240
Utility Sector, Demand	4,906
Technical and Financial Assistance,	
Technical Assistance and Deployment	265,069
Policy and Management—Energy	
Conservation, Other	3,617

ity, and enhance competitiveness in U.S. industry. Its activities included the continued development, with the steel industry, of a direct steelmaking process and other new steelmaking technologies that are more energy efficient and less polluting than conventional processes. Other programs included developing ways to produce new continuous-fiber ceramic composite components with a wide variety of industrial applications, working on technologies that mitigate or eliminate waste production at the

source, and developing advanced gas turbine systems for cogeneration applications.

4. The Office of Building Technologies seeks to increase energy efficiency in buildings. As part of the program, the office developed special storage materials, advanced windows, and innovative building materials. Researchers also continued to study passive solar designs as well as to work on improved interior building components—high efficiency lighting, appliances, and heating, ventilating, and air-conditioning equipment. Other initiatives included establishing and updating energy efficiency standards for appliances and other equipment and working with professional and public organizations to improve efficiency standards for new buildings. DOE also cooperated with other Federal agencies and utilities to demonstrate the energy savings potential of residential and commercial buildings.
5. The Office of Technical and Financial Assistance coordinates partnerships with industry, government, consumers, and others to commercialize energy efficiency research advances. DOE's regional support offices serve as information and technology transfer conduits. The office works with states and local governments to improve their planning for, and management of, energy resources. It also administers several technical and financial assistance programs, including weatherization assistance and state energy conservation and institutional conservation programs.

To help expand the use of energy efficiency technologies in the marketplace, DOE has aggressively pursued partnerships with other Federal agencies and the private sector. In the Federal sector, an innovative program between DOE and the Department of Housing and Urban Development will help reduce energy use in federally assisted housing, saving taxpayers' money and improving the overall quality of life for residents in those dwellings. The goal of the federally assisted housing program is to achieve by the year 2000 overall energy savings of up to 25 percent.

To improve energy efficiency in industry, DOE has undertaken programs with a variety of participants in the manufacturing sector. Prominent among these is the joint project by the Department and the American Iron and Steel Institute to develop a process for making steel without producing coke, the most energy-intensive and environmentally harmful step in making steel.

The Department continues to improve energy efficiency in the home by issuing energy efficiency standards for home appliances. More efficient appliances will not only reduce

energy demand but also save consumers money over the lives of the products. In 1993, DOE completed its analysis of a proposed standards rulemaking for room air conditioners, water heaters, direct heating equipment, mobile-home furnaces, kitchen ranges and ovens, pool heaters, fluorescent-lamp ballasts, and television sets.

UTILITY TECHNOLOGIES

In 1992, electric and gas utilities accounted for 57 percent of the primary energy used in the United States. The 30 quadrillion British thermal units (quads; 32 exajoules) of primary energy used by the electric utilities came from diverse sources: coal, oil, nuclear fuel, natural gas, hydropower, and biomass.

The mission of the Office of Utility Technologies is to work with industry to develop cost-effective technologies for efficient energy use and supply and to promote their commercialization and use by utilities and others, as well as to help utilities plan and acquire resources on the basis of greatest net benefit to consumers. Utilities, regulators, and DOE are pursuing improved end-use energy efficiency and load management to offset demand growth and reduce the number of powerplants that will have to be built. Improved energy efficiency standards for homes, commercial buildings, appliances, lighting, and load management technologies could reduce both growth in electricity consumption and the environmental impacts of energy production. Technologies that will strengthen the transmission and distribution systems, improve utility system efficiency, and enable the integration of diverse renewable energy resources are also being developed.

The office carries out its mission in conjunction with the states and the utility sector. Within this mission, the Office of Energy Management is responsible for developing and promoting the adoption of cost-effective energy storage, transmission, and distribution technologies. The office also supports development of high-temperature superconducting wire for application in high-temperature superconducting electric utility system equipment. Research and development (R&D) on hydrogen focuses on methods to produce hydrogen from renewable energy sources as well as storage, transport, and end-use technologies.

EPACT has required the expansion and acceleration of numerous programs within the Office of Utility Technologies, including integrated resource planning, research on the health effects of exposure to electromagnetic fields, high-temperature superconductivity R&D, and R&D on hydrogen.

Integrated Resource Planning

Integrated resource planning (IRP) involves analyzing and evaluating a full menu of supply- and demand-side resource options in determining the best way for utilities to meet the energy needs of their customers. Utilities can use IRP to improve systemwide efficiency, increase effective asset use, and implement cost-competitive and innovative technologies. IRP is fuel- and technology-neutral in the identification and estimation of costs and benefits of alternative resource options. It is an evolving process, driven by rapid changes in the structure of U.S. energy markets, including many that will result from EPACT (EPACT requires a broadening and acceleration of IRP). These changes will increase the number of energy resource options and provide access to the electric and gas transmission infrastructure to parties that previously did not have access. The majority of states now require IRP for electricity or gas or both; however, in most cases these practices are still in their infancy. A central role of DOE's IRP program is to help states and utilities implement and follow through on IRP activities as well as to monitor and evaluate the results.

IRP offers significant opportunities for the Nation to use energy more efficiently. As demand for energy increases over the next 20 years, the utility sector could invest more than \$200 billion in new plants and equipment. DOE estimates that demand-side management, induced by IRP, could reduce the growth in electrical-generating-capacity requirements by more than 50,000 megawatts (MW) by 2010 and save about 245 billion kilowatthours (882 petajoules). IRP also encourages earliest reasonable consideration of nontraditional supply options such as renewable energy technologies; thus, utilities may add as much as 1.0 quad (1.1 exajoules) of nontraditional technologies to the resource mix. Using IRP, utilities can respond to these changes in a manner that is technologically, economically, and environmentally responsible and that ensures low risk and reliable energy services for consumers. Utilities can achieve effective IRP by realizing opportunities in such areas as the following:

1. *Energy and environmental efficiency:* The new generation of clean and efficient energy technologies can make an important contribution to economic competitiveness and environmental integrity. The growth of markets for these technologies is a function of their technical, environmental, and cost competitiveness, and IRP is a vehicle that allows the

consideration of all technology options in an equitable manner.

2. *Utility asset utilization:* IRP can help illuminate the benefits of more efficient utility operations that optimize generation, storage, transmission, distribution, and end use. Achieving higher system efficiencies may call for new market configurations, structures, and interrelationships. DOE's IRP program will track these industry developments and encourage activities that will achieve higher levels of asset utilization.
3. *Advanced utility systems:* Advanced technologies and concepts for employing these technologies in the utility system can improve the overall quality of service. IRP provides the means to evaluate new technologies on an equal basis with other options for meeting the utility's customer needs.
4. *Public participation:* IRP provides a framework for identifying, evaluating, and debating a wide range of impacts and consequences associated with various resource alternatives, and thus it can be used to achieve more robust decisions in resource selections.
5. *Open access to energy markets:* More open access to energy markets is changing the way energy markets and producers operate. IRP provides a means of systematically evaluating these new opportunities and more easily discovering the preferred least-cost and environmentally sound resource options.
6. *IRP extensions:* Utility service territories and the effects of utility decisions are not bound by jurisdictional or political boundaries of states. IRP can be modified and adapted for regional planning, for other sectors of the economy, or for international markets.

DOE's IRP program has helped states and utilities recognize the broadest possible range of opportunities. Recognizing that regions, states, and utilities are best equipped to develop their own IRP strategies, the Department has sought to act as a focal point and catalyst for nurturing the evolution, understanding, and effective implementation of results-oriented IRP practices. In 1992 and 1993 the IRP program performed activities to achieve the following goals:

1. *Increase the availability and enhance the quality of methods, analytical tools, and data:* The program improved the analytical resources available to planners. Through Lawrence Berkeley Laboratory (LBL), the national Database for Energy Efficient Programs helped utilities to evaluate and verify the costs and performances of demand-side resources

and to improve the reliability and effectiveness of future demand-side programs. With Oak Ridge National Laboratory (ORNL), the program focused on the development of modeling capabilities to evaluate demand-side management as a strategy for Clean Air Act compliance. The goal of this collaboration was to develop the capability to estimate sulfur dioxide reductions and compliance costs resulting from energy conservation actions at the local, state, regional, and national levels. In collaboration with the Electric Power Research Institute, the Bonneville Power Administration, and several major utilities, DOE established the Center for Electric End-Use Data to serve as a national clearinghouse for metered end-use and load shape data for demand-side management measurement and evaluations, load and sales forecasting, end-use technology assessments, and cost allocations for ratemaking. The National Renewable Energy Laboratory began testing a fuel cycle assessment guide in Maryland. The guide would allow state and utility planners to consider all external costs and benefits associated with each stage of an energy technology's fuel cycle.

2. *Enhance information transfer and focus project activities on issues facing the industry:* The program provided outreach and technical assistance on issues facing the utility industry. DOE continued to provide a demand-side management and IRP handbook and data base and to hold advanced IRP seminars at LBL. The Department held a major IRP meeting in Washington, D.C., for utility chief executive officers from around the country to identify and address major IRP-related issues facing the industry. In addition, the Department held a practitioners workshop with representatives of utilities, public utility commissions, and industry to assist them in program review and issue identification.
3. *Analyze and mitigate barriers to IRP:* With state energy officials and regulators, the program developed a better understanding of load management and efficiency investments by utilities as well as financial disincentives to demand-side management. These efforts helped DOE to develop a menu of ratemaking strategies to overcome these disincentives. Also, the program examined market barriers to the use of renewable energy technologies.
4. *Respond to specific requirements in EPACT:* Although gas IRP is in its early stages, the program worked closely with gas utilities and state regulators to assist them in modifying current IRP practices for gas utilities.

In continuing to support the evolution of IRP and the implementation of IRP practices, DOE's IRP program focused on new activities that would expand and draw upon its previous successes. Through these activities, the Department plans to expand participation to nonpracticing states, utilities, power marketing agencies, and consumer groups; expand IRP methods to include regional, gas utility, fuel cycle, and risk analyses; and evaluate the progress of IRP nationally to ensure that IRP practices generate meaningful results.

Energy Management and Control

Electric Energy Systems

DOE's transmission and distribution program supports R&D on technologies that will provide the capacity and flexibility for transmission and distribution networks to fully integrate and utilize all the resources evaluated under integrated resource planning. Another key thrust of this program is to develop cost-effective technologies to transmit more power over existing transmission corridors. The Department's R&D programs also include investigating the potential health effects of exposure to electric and magnetic fields, developing energy storage technologies, and developing superconductivity technologies. The transmission and distribution technologies and the storage technologies research programs, in particular, work to increase network flexibility and resiliency and to improve transmission access for new dispersed generation technologies, such as photovoltaics, wind, and solar thermal systems. The superconductivity R&D program aims to reduce electric losses; for example, a 10-percent decrease in electric transmission and distribution losses could save 35 billion kilowatthours (130 petajoules), or more than \$1 billion, nationwide.

Electric and Magnetic Field Effects

In recent years, there has been increasing public concern regarding health effects from exposure to electric and magnetic fields generated by electric transmission and distribution lines and by equipment that uses electricity. The construction of some new transmission lines has been halted or delayed by public concerns about electric and magnetic fields. The electric and magnetic field effects program supports research to resolve these concerns and communicates results and information to the public.

In 1993, DOE circulated for public review a draft strategic plan for the National Electric and Magnetic Field Research and Communication Program. The Department developed the plan through workshops, public meetings, and a consensus among the government, public, and business sectors. The plan provides a roadmap for the coordinated implementation of research and communication activities to address the public's concerns and meet the needs of decision-makers.

The Department also continued its ongoing biological mechanisms research and implemented many of the provisions of the expanded and accelerated program authorized by section 2118 of EPACT. During 1993, both the Advisory Committee and the Interagency Committee were established. DOE and the National Institute of Environmental Health Sciences are positioned to implement research and communications activities with the 1994 appropriation and non-Federal contributions.

Transmission and Distribution Technologies

Based on strategic planning with the utility sector and manufacturers, the 1993 DOE research programs for electric transmission and distribution systems were primarily directed toward technologies to achieve real-time systems control and operation and also toward methods to increase the power flows over existing transmission corridors. In 1993, in partnership with the utility sector, DOE initiated the multiyear development of real-time systems and control technologies for advanced transmission and distribution systems. Real-time systems control and operation technologies would allow generation (including renewable energy), energy storage, and demand-side management resources to be fully integrated and dispatched into transmission and distribution systems. These technologies would also provide more efficient power dispatch, with highly reliable operation at a lower capacity margin.

In 1992, DOE demonstrated the economic and engineering feasibility of a two-way real-time communication medium for distribution systems, based on fiber-optic technology. In 1993, the Department conducted an actual field test, which was cost-shared with a utility and a manufacturer of this technology.

During 1993, DOE, in partnership with utilities, supported an operational test of a six-phase transmission line. The Department expects that this cooperative demonstration project will confirm the operational viability of a six-phase system, which can provide up to 70 percent more line capacity than a three-phase system. In addition, a six-

phase system would reduce the electric and magnetic field levels at the edge of the right-of-way.

In 1993, DOE also initiated the multiyear development of advanced high-voltage direct-current transmission systems to reduce converter station costs by 40 to 50 percent. This technology could double the power flow over existing rights-of-way and provide excellent power flow control.

High-Temperature Superconductivity

About 8 percent of the electrical energy generated by utilities is lost in the transmission and distribution of that energy. High-temperature superconductivity—the ability to conduct electricity without resistance at a temperature significantly higher than absolute zero (-273 degrees Celsius (-273°C))—may one day eliminate much of this loss. High-temperature superconductivity may also lead to more efficient generators, storage devices, and motors. Recent high-temperature-superconductivity discoveries have prompted a worldwide technological race, with a projected annual market of more than \$5 billion by the year 2000. DOE has the lead Federal role in high-temperature superconductivity R&D in the area of high-current electric power applications.

The DOE high-temperature superconductivity program has put the United States in a leadership position in the critical technology of developing electric wires from high-temperature superconductivity materials. Effective teams that build on the two U.S. strengths—the entrepreneurial drive of small companies and the talents and resources of the national laboratories—have been formed. This effort responds to section 2117 of EPACT, which mandates “activities that address the development of high-temperature superconducting materials that have increased electrical current capacity, which shall be the emphasis of the program for the near term.” The more than 80 agreements to date have kept U.S. companies in the forefront of wire manufacturing technology. Three of those companies—American Superconductor (Cambridge, Massachusetts), Conductus (Sunnyvale, California), and Superconductor Technologies (Santa Barbara, California)—were created in 1987, following the discovery of the first high-temperature superconductors, and now employ between 150 and 200 people in high-technology positions.

Companies participating in the program can now manufacture 600-meter lengths of high-temperature-superconductivity wire capable of carrying large currents in high fields. Their emphasis is now on production scaleup while they continue to improve performance and lower costs.

Under a competitive solicitation, this year's DOE Superconductivity Partnership Initiative made awards that provide financial assistance to industry teams intending to commercialize electric power products that use high-temperature superconductivity. These partnerships are excellent examples of DOE and industry cooperatively sharing the costs and risks of developing critical technologies.

Three vertically integrated industry teams (including a superconductivity component supplier, a product manufacturer, and a user—in this case, an electric utility) have received Superconductivity Partnership Initiative assistance awards. Supporting tasks performed by the national laboratories will be funded separately. The teams will develop designs and components for superconductive generators, motors, and fault current limiters. Their success will result in more efficient electricity production, delivery, and use (with a corresponding reduction in environmental impact) as well as several billion dollars in economic opportunity, primarily in exports.

The teams represent major U.S. economic strengths—three of the Nation's largest corporations in General Dynamics (San Diego, California), General Electric (Schenectady, New York), and Reliance Electric (Cleveland, Ohio); three major electric utilities in Southern California Edison (Rosemead, California), Niagara Mohawk (Syracuse, New York), and Centurion Energy (Cleveland, Ohio); two entrepreneurial small companies in American Superconductor (Westborough, Massachusetts) and Intermagnetics General (Guilderland, New York); and four DOE National Laboratories (ANL, LANL, ORNL, and SNL). State agencies and the Electric Power Research Institute are also team members.

District Heating and Cooling

Large, centralized district heating and cooling systems can provide efficient, reliable, more environmentally sound, and cost-effective alternatives to smaller systems in individual buildings. For more than a decade, the District Heating and Cooling Program has focused on improving the cost and the energy efficiency of these systems and on increasing their market penetration. In 1993, the District Heating and Cooling Program was in the process of being closed out with 1992 appropriations. Activities completed include a characterization of district heating and cooling systems in the United States, research on ice slurries and friction-reducing additives, and the administration of issued grants to facilitate the use of advanced district cooling systems and cogeneration applications.

Energy Storage Systems

The Energy Storage Program supports R&D on advanced technologies to provide new options for the Nation's energy delivery infrastructure. Technology developed through this program will also facilitate the integration of renewable energy into the Nation's energy delivery systems.

Utility Battery Storage

The Utility Battery Storage Program supports efforts to develop cost-effective and reliable advanced battery systems for utility applications. Battery systems offer a range of benefits that will make them an important link in the utility system of the future. A utility can use a battery system to reduce the stress on an individual transmission line that is near its peak rating by reducing substation peakload. The same battery system can also provide both voltage stability and regulation, and it can increase the power quality and reliability for specific customers. A customer can use a battery system to trim peak power demand, thereby saving the customer money while providing a demand-side management resource to the utility. In combination with renewable energy systems, batteries can permit greater use of photovoltaics and wind resources.

The elements of this comprehensive battery program include battery systems analysis, subsystem engineering, system integration, system field evaluation, and industry outreach. Key projects include feasibility studies to evaluate the costs and benefits of battery storage systems; development of lower cost and higher performance components, with emphasis on improved and advanced battery technology; integration of components into complete, packaged systems for purchase by utilities; field validation and performance testing of complete systems; and transfer of information via the Utility Battery Group. The goal of this Government-industry partnership is the use of battery storage as a cost-effective energy resource option by the Nation's utilities and their customers.

In 1992, engineering development continued on factory-integrated, modular battery systems. The first prototype module using commercially available batteries was fabricated and delivered to a host utility, where testing began. In 1993, DOE began developing transportable utility battery systems in close coordination with the Electric Power Research Institute.

Thermal Energy Storage

DOE has estimated that U.S. industry annually generates approximately 11 quads (12 exajoules) of waste heat. Much of this waste heat could be recovered for reuse through thermal energy storage technology. The Department is supporting improved energy use through a targeted thermal energy storage R&D program directed toward power generation, space heating and cooling, and industrial applications.

DOE's support for R&D on thermal energy storage for space and process heating and cooling applications is focused on technologies that reduce peak electric loads, increase energy efficiency, reduce emission of greenhouse gases, and enable the use of renewable energy sources. The Department's efforts have produced a number of technologies, particularly for food processing in the industrial sector. In 1993, efforts cosponsored by DOE and industry also focused on development of thermal energy storage concepts for cogeneration and peakload averaging in the utility sector.

Cogeneration activities supported by DOE in 1993 encompassed evaluation and assessment of promising molten-salt thermal energy storage concepts; development and commercialization of a thermal energy storage technology that improves the cost and performance of gas turbines through inlet air-cooling systems; and demonstration, testing, and evaluation of high-temperature composite phase-change thermal energy storage material integrated into a natural-gas-fired cogeneration test-bed.

Hydrogen Research

The Hydrogen Research Program has been reconfigured to focus on R&D critical to the development of long-term hydrogen energy systems capable of supplying large amounts of hydrogen for a variety of end-use fuel applications. The Department's comprehensive hydrogen multiyear plan, submitted to Congress in May 1992 in compliance with the Matsunaga Act (Public Law 101-566), assigned the highest priorities to the development of direct hydrogen production methods and the development of storage technologies. In accordance with the plan's priorities and title XX, section 2026, of EPACT, the program is implementing projects to develop selected renewable direct hydrogen production technologies (for example, those using photoelectrochemical and photobiological methods) and will begin collaborating with industry to develop high-density energy storage concepts and to assess the feasibility of modifying existing natural gas pipelines to transport mixtures of hydrogen and natural gas.

TRANSPORTATION TECHNOLOGIES

Introduction

The large impacts of the transportation sector, especially highway vehicles, on the Nation's petroleum use, the environment, and the economy are well recognized. The transportation sector is the major contributor to the growing dependence of the United States on imported petroleum. In 1992, the U.S. transportation sector consumed 22.4 quads (23.6 exajoules) of energy, 27 percent of the total U.S. energy consumption (Figure 1-1). Ninety-seven percent of the transportation energy use was petroleum-based, primarily in the form of gasoline, diesel, and jet fuel. Transportation petroleum use averaged 10.3 million barrels (1.40 million metric tons) per day in 1992, constituting 65 percent of the total U.S. petroleum use and exceeding U.S. petroleum production by 43 percent. These data clearly indicate that efforts to reduce the Nation's growing dependence on imported petroleum must target the transportation sector (Figure 1-2).

Transportation energy use has increased steadily since the early 1970s, despite significant vehicle efficiency improvements (Figure 1-3). DOE projects that this trend will continue, driven by a consistent rise in demand for transportation services (Figure 1-4). The Energy Information Administration has projected transportation energy use in the year 2010 as 28.93 quads (30.52 exajoules), which represents an annual average growth rate of 1.3 percent from 1990 to 2010. The Energy Information Administration also projects that energy use by light-duty vehicles, which currently accounts for about 60 percent of transportation energy use, will grow at an annual rate of 1 percent, and that energy use by other (heavy-duty) transport modes will grow at higher rates.

The transportation sector, including both light- and heavy-duty vehicles, is the major contributor to air quality problems in urban areas. Although emissions per vehicle-mile today are about 80 percent below 1970 levels, because of the dramatic increase in vehicle-miles traveled, the transportation sector produces two-thirds of national carbon monoxide emissions, almost 40 percent of nitrogen oxide (NO_x) emissions, and about one-third of the lead and volatile organic compound emissions (Figure 1-5). Nitrogen oxide and volatile organic compounds are the primary contributors to ozone and smog formation in urban areas. Moreover, DOE forecasts that without technological breakthroughs, adverse energy and environmental

1-1. Transportation energy and petroleum use, 1992. Source: Energy Information Administration, 1993.

impacts will increase at a rate that will offset gains in new-vehicle efficiency and emissions control because of projected increases in the vehicle fleet size and in distances traveled.

Government policy-makers and regulators in areas with severe air quality problems, such as southern California, recognize that dramatic emissions reductions from even the best current practice will be necessary in order to meet regulatory requirements. This recognition is reflected in the highly publicized requirements of the California Low Emission Vehicle Program to introduce zero-emission vehicles into the California fleet before the end of the decade. Several other states, representing more than 30 percent of the national vehicle market, are also considering adopting these requirements. As of June 1993, five states besides California had adopted low-emission-vehicle programs: Maine, Maryland, Massachusetts, New Jersey, and New York.

Transportation is a key component of the U.S. economy (Figure 1-6). Total freight and passenger transportation expenditures accounted for almost 18 percent of the gross domestic product (\$975 billion) in 1991. Motor vehicle and related industries provided about 7.1 million jobs in 1990. Unfortunately, employment in the automotive in-

1-2. Transportation energy use by mode and fuel, 1991. Source: Oak Ridge National Laboratory, 1993.

1-3. Historical trend of transportation energy consumption, 1970–91. Source: Oak Ridge National Laboratory, 1993.

dustry has been declining for several years because of a decline in vehicle sales to foreign competition and productivity improvements. Transportation accounts for about 11.3 percent of household expenses; annual spending on new automobiles is about \$85 billion, and annual spending on fuel and oil is about \$105 billion. In addition, oil and motor vehicle imports are major contributors to trade deficits.

In 1992, U.S. balance-of-trade deficits included about \$46.6 billion of net oil imports and \$44.5 billion of net imports of motor vehicles and parts. Such high trade deficits pose serious threats to U.S. energy security and economic strength and also represent a major challenge to the Nation's competitiveness and technological leadership in motor vehicle production.

Improvements in vehicle efficiency, fuel flexibility, emissions, reliability, and safety will reduce energy, environmental, and health-related costs and create a stronger economy. Investment in transportation R&D has distinct national benefits. For example, a 10-percent reduction in gasoline use by automobiles and light trucks (through efficiency improvements) would save about 11 billion gallons (42 billion liters) of gasoline per year—representing about \$13 billion in annual fuel cost savings

to the public. In addition, such a reduction would contribute to corresponding reductions in crude oil imports and in trade deficits.

Scope of Program

In accordance with EPACT, the goals of the DOE Transportation Technologies Program's balance of near-, mid-, and long-term R&D on transportation technologies is to reduce transportation oil demand through cost-effective improvements in fuel efficiency. The Department is focusing on improving the efficiency and fuel flexibility of automobiles and light trucks, which account for about 60 percent of transportation petroleum use, and of heavy trucks and buses, the second-largest petroleum-consuming market. An underlying goal of the program is to support industry in meeting stringent future emissions standards for light- and heavy-duty vehicles.

The program's near-term emphasis is on developing engines that can use alternative fuels and on developing ceramic components that enable the engines to operate at higher temperatures and with increased efficiencies. A

I-4. Relationship of dependence on imported oil and transportation petroleum use. Source: Oak Ridge National Laboratory and Energy Information Administration, 1993.

recently initiated program has targeted hybrid/electric vehicles based on available and near-term technology. The Department's advanced transportation materials development activities focus on providing a technology base that will enable industry to produce reliable and cost-effective components for advanced heat engines, to address emissions control catalyst and alternative-fuel engine requirements, and to reduce the weight of vehicle structures.

DOE expects midterm accomplishments in vehicle propulsion to include automotive gas turbines and the next generation of low-emission, high-efficiency diesel engines for heavy-duty vehicles. In addition, with DOE support, industry contractors are developing critical component and vehicle system technologies to accelerate the commercial introduction of 250-mile- (400-kilometer-) range electric vehicles and unlimited-range, ultralow-emission hybrid vehicles. Long-term projects will likely lead to cost-competitive zero-emission electric vehicles and fuel cell vehicles with ranges and performances equivalent to those of conventional, gasoline-powered vehicles.

The Transportation Technologies Program's demand-related R&D activities target advanced vehicle propulsion (including heat engine and electric and hybrid propulsion) and advanced transportation materials. These activities are

mandated by the Automotive Propulsion Research and Development Act of 1978 (title III of Public Law 95-238) and the Electric and Hybrid Vehicle Research, Development, and Demonstration Act of 1976 (Public Law 94-413). Electric and hybrid propulsion, especially battery development, receives the largest funding among the Transportation Technologies Program's demand-related elements, followed by advanced materials and heat engines.

Advanced Vehicle Propulsion

The successful introduction of advanced propulsion systems into the Nation's vehicle fleet would provide a pathway to improved fuel economy, fuel flexibility, and lower emissions. Efficiency improvements combined with petroleum substitution should substantially reduce oil consumption. Based on DOE's recent analysis conducted in support of Transportation Technologies Program planning, the combination of high-efficiency and alternative-fueled vehicles and battery-powered electric vehicles, hybrid vehicles, and fuel cell vehicles penetrating the light-duty-

1-5. Transportation sector's share of environmental emissions, 1991. Source: Environmental Protection Agency, 1992.

vehicle market could displace transportation petroleum use by about 0.4 million barrels (55,000 metric tons) per day by the year 2000, and grow to 1.6 million barrels (220,000 metric tons) per day by 2010 and 3.0 million barrels (412,500 metric tons) per day by 2020 (Figure 1-7). This projected impact is quite substantial—potentially reversing the trend of ever-increasing transportation petroleum use and oil imports.

DOE estimates potential year-2030 reductions in total light-duty vehicle emissions of 4 percent for carbon monoxide, 3 percent for nitrogen oxides, and 4 percent for hydrocarbons. The cumulative savings in environmental control costs through 2030 could exceed \$9 billion in constant 1992 dollars. Significant economic benefits would also accompany successful commercialization of DOE-developed technologies: more than 700,000 jobs and more than \$52 billion growth in gross domestic product in 2010, with a net increase in gross domestic product of more than \$100 billion by 2030.

Advanced Gas Turbine Engines

The advanced gas turbine automobile has broad multifuel capability and the potential for ultralow emissions. It also could improve fuel economy 30 percent compared with the conventional piston engine automobile. This efficiency

improvement can be achieved with a peak cycle temperature of about 2,500 degrees Fahrenheit (2,500°F), or about 1,370°C. The Advanced Turbine Technology Applications Project, which DOE is pursuing with the Engines Division of AlliedSignal Aerospace Company (Phoenix, Arizona) and the Allison Gas Turbine Division of General Motors Corporation (Indianapolis, Indiana), addresses this critical technological requirement for high-temperature operation by supporting the design, fabrication, testing, and development of components made from advanced, high-temperature structural ceramics.

Program accomplishments in 1992 and 1993 included designing and testing the improved durability and aerodynamic performance of ceramic turbine rotors; increasing the use of improved components manufactured by U.S. ceramic companies; sponsoring supplemental ceramic regenerator and combustor technology efforts to reduce fuel consumption, emissions, and potential manufacturing costs; nearing completion of 300 hours of cyclic durability testing of an all-ceramic test-bed engine at Allison; refocusing the Advanced Turbine Technology Applications Project to support development of small gas turbine engines as the auxiliary power unit for hybrid vehicles; and continuing a demonstration of ceramic components installed and operated in a modified production gas turbine auxiliary power unit at AlliedSignal.

1-6. Economic impacts of transportation, 1991-1992. Source: American Automobile Manufacturers Association, 1993.

Improved Diesel Engines for Heavy-Duty Transport

The Heavy Duty Transport Technology Program focuses on improving the efficiency, reducing the emissions, and enhancing the alternative-fuel capability of diesel engines while complying with increasingly stringent emission standards established by the Environmental Protection Agency (EPA) for heavy-duty vehicles. The diesel engine is the workhorse of the heavy-duty transport sector, which accounts for more than 25 percent of U.S. transportation energy use and contributes a substantial share of transportation sector emissions.

DOE continued to support the development of the technology for low-emission, 55-percent-efficient (LE-55) diesel engines for heavy-duty trucks at Cummins Engine Company (Columbus, Indiana); Caterpillar, Inc. (Peoria, Illinois); and Detroit Diesel Corporation (Detroit, Michigan) in 1992 and 1993. This 55-percent-efficiency program goal represents a 30-percent improvement over the efficiency of current production engines. Cummins and Caterpillar initiated single-cylinder-engine testing of LE-55 engine components. Fuel economy projections for a multicylinder engine were within 5 percent of the program goal. Cummins completed fabrication of a spherical-joint piston for its LE-55 engine. Ricardo North America (Burr Ridge, Illinois), in cooperation with Caterpillar, has developed a computer model of diesel engine piston and ring pack performance. In addition, Caterpillar has demonstrated a 4-percent improvement in fuel

economy over current production diesel engine using combustion chamber components with thermal barrier coatings to reduce cylinder heat rejection. Appropriate adjustments to the fuel injection equipment were required to compensate for hot-wall effects.

To help domestic diesel engine manufacturers meet the stringent heavy-duty-vehicle emission standards that EPA has stipulated for 1998 and beyond, the Department is exploring a range of engine and fuel modifications and exhaust aftertreatment approaches. Planning is under way to initiate the Advanced Diesel Emissions Program required by EPACT. Without the development of advanced emission reduction technologies, meeting stringent future emissions standards is likely to significantly reduce the fuel economy of heavy-duty vehicles. A major project with Cummins and Texaco R&D Center (Beacon, New York) is developing a promising nitrogen oxide- (NO_x -) reducing additives for diesel fuel based on cyanuric acid chemistry. Initial engine tests are promising, with the additive producing a 46-percent reduction in NO_x . DOE initiated development of an electronic NO_x reduction system based on the oscillating-wave principle in a joint project with the South Coast Air Quality Management District (Diamond Bar, California). The Department also initiated a joint project, with the California Energy Commission (Sacramento), to support the use of laser diagnostics to follow NO_x -reducing additives in a single-cylinder diesel test engine. Another project demonstrated the high-temperature lubrication qualities of a low-ash synthetic liquid lubricant and its potential for reducing emissions.

I-7. Potential impact of the DOE Transportation Technologies Program strategy on reducing transportation petroleum use by the year 2020. Source: DOE Office of Transportation Technologies.

The Department is also developing technology to enhance the alternative-fuel capability of diesel engines. It completed proof-of-concept tests of a fuel additive solution for plugging and excessive wear in fuel injectors for methanol engines. The additive reduced fuel injector maintenance by a factor of 3. In a joint program with Transport Canada, DOE developed a prototype continuously operating glow plug for methanol operation that showed significant advantages over current glow plugs.

Transportation Climate Control Systems

Transportation climate control R&D focuses on developing of environmentally sound, highly efficient climate control systems for advanced vehicles, including electric, hybrid, fuel cell, and gas turbine vehicles. Not only does the imminent phaseout of stratospheric-ozone-depleting chlorofluorocarbon (CFC) refrigerants necessitates such systems, but advanced vehicles' heating, ventilation, air-conditioning, and defrosting-defogging systems also must be optimized for the vehicles' unique characteristics. These systems must be fully integrated into the vehicle designs and incorporated into the vehicles' control and energy management systems.

In 1992 and 1993, DOE-supported research focused on reducing the thermal load of vehicles and increasing the efficiency of climate control equipment. Oak Ridge developed a liquid overfeed system that improved in air-conditioning-system efficiency by 20 percent in laboratory tests. ORNL also assembled an automotive climate control system in an environmental chamber to simulate a vehicle and its surroundings and tested the device under dynamic and extreme temperature conditions. At Lawrence Berkeley researchers conducted computer modeling studies to better understand the vehicle thermal envelope (the various components of the passenger compartment's heating and cooling load). They measured the effects of various means of insulating the passenger compartment and reducing the energy requirements of the climate control system.

Magnetically Levitated Transportation

In December 1990, DOE, the Department of Transportation, the Army Corps of Engineers, and other agencies formed the National Maglev Initiative to coordinate research for and evaluation of magnetic levitation (maglev) technology. The goals of this initiative were to evaluate

maglev's potential for improving U.S. intercity transportation and determine the appropriate role of the Federal Government in advancing maglev technology. The National Maglev Initiative has funded 27 contracts for assessing particular technologies crucial to the implementation of maglev systems. The initiative has awarded four contracts to develop alternatives for maglev systems concept definitions. In addition, the initiative has expended a substantial effort to address economic, market, and institutional issues.

The National Maglev Initiative has issued a final report with recommendations on future Government actions regarding maglev. The recommendations are based on private-sector and Government information generated during the past 3 years. The report concluded that the potential benefits are sufficient to justify a national maglev development program. In the course of such a program, the remaining technological, economic, and environmental questions must be fully addressed so that maglev's full potential in an integrated transportation system can be understood.

The maglev initiative also recommended that the Federal Government initiate the first phase of a competitive program to develop an advanced maglev system. To benefit from recent maglev developments abroad, joint ventures between U.S. and foreign companies should be permitted to the extent that development activities take place in the United States. Finally, because of the estimated development costs (about \$800 million) and the technological and financial risks involved, the viability of the program should be periodically reevaluated (First in December 1994, and after each developmental phase thereafter).

Electric and Hybrid Vehicles

The successful penetration of electric and hybrid vehicles into the Nation's vehicle fleet would increase its energy efficiency and allow the transportation sector to meet its demand for energy partially with electricity. This would reduce the fleet's high dependence on petroleum fuels, because only about 4 percent of the electricity in the United States is generated from petroleum. Meeting transportation energy needs with centralized electricity generation also would provide greater fuel flexibility, especially in terms of opportunities for renewable energy use, when compared with fuel combustion aboard vehicles.

Relative to internal-combustion-engine vehicles, electric and hybrid vehicles would also help to reduce severe urban pollution problems, because emissions from fuel

combustion would be partly (in the case of hybrid vehicles) or fully (in the case of electric vehicles) removed from the street level and, in most cases, from the urban area. Electric vehicles would be essentially nonpolluting if they used electricity generated from nonfossil fuels. Even in areas where the electric power generation is almost exclusively from fossil fuels, the substitution of electric vehicles for gasoline-fueled vehicles would result in net reductions of carbon monoxide, hydrocarbon, and nitrogen oxide emissions. In economic terms, large national gains could result from creating and expanding domestic and international markets for domestically produced electric and hybrid vehicles. Enhanced vehicle efficiency and fuel flexibility would also translate into economic benefits for vehicle users as well as for the population areas where pollution would be abated with these vehicles. Economic savings will accrue from environmental and health benefits and lower environmental control costs.

Recognizing the large potential for energy, environmental, and economic benefits to the Nation, the Department is devoting considerable resources to an Electric and Hybrid Vehicle Program focused on developing critical component and vehicle systems technologies that will enable industry to commercialize a 150-mile- (225-kilometer-) range electric vehicle and demonstrate an unlimited-range, ultralow-emission hybrid vehicle by the year 2000, and to commercialize cost-competitive, zero-emission vehicles whose range and performance are equivalent to those of conventional gasoline-powered vehicles by 2005. The specific objectives of the Electric and Hybrid Vehicle Program are based on achieving steady improvements in key technologies, such as batteries, high-power capacitors, fuel cells, and propulsion systems, enabling industry to provide commercially acceptable vehicles that should capture a larger market share as the technologies progress.

Advanced Batteries

The development of high-performance, low-cost, reliable, and safe batteries is essential to the successful commercialization of electric vehicles. To become a viable commercial product over the long term, electric vehicles must economically provide the range, performance, personal comfort, and trouble-free operation currently available with conventional gasoline-fueled vehicles.

The Advanced Battery Program is working through a cooperative agreement with the U.S. Advanced Battery Consortium (USABC) to support the development of the most promising rechargeable battery technologies for electric vehicles. This fifty-fifty cost-shared partnership is

supporting teams of advanced battery developers and manufacturers (working in conjunction with the national laboratories) in achieving specific mid- and long-term goals (set by automobile manufacturers) for advanced batteries. The partners have selected nickel-metal hydride and sodium-sulfur batteries as potential mid-term candidates and lithium-polymer and lithium (aluminum)-iron disulfide as promising candidates to meet long-term battery goals. The battery developers will deliver prototype midterm batteries to the USABC in 1994 for laboratory and field testing, and pilot-level production is scheduled for 1995.

Since signing the cooperative agreement in early 1992, the USABC and DOE have worked together in selecting the advanced battery systems for R&D to meet the USABC goals. DOE and the USABC have refocused advanced battery R&D efforts; DOE gradually phased out projects that it had supported before the formation of the USABC, and the USABC initiated new projects. In cooperation with industry, DOE established the Battery Test Procedures Working Group to address testing issues and to ensure that the program for battery testing is comprehensive and uniform. In 1992, the USABC focused on selecting potential contractors and negotiating suitable agreements for the development of advanced batteries. New contracts and cooperative research and development agreements (CRADAs) signed in 1992 and early 1993 included a contract with Ovonic Battery Company (Troy, Michigan) for nickel-metal hydride battery development, a contract with a W. R. Grace and Company (Boca Raton, Florida)-Johnson Controls (Milwaukee, Wisconsin) team and a CRADA with LBL and Sandia National Laboratories for development of lithium-polymer battery technology, a contract with SAFT America (Cockeysville, Maryland) and a CRADA with Argonne National Laboratory for development of lithium (aluminum) iron disulfide battery technology, a contract with Silent Power Limited for development of sodium-sulfur battery technology, CRADAs with Argonne and Idaho National Engineering Laboratory for testing advanced batteries, and a CRADA with the National Renewable Energy Laboratory to develop advanced insulation for high-temperature batteries. In addition, the USABC announced the purchase from Ovonic Battery Company of five nickel-metal hydride vehicle battery packs for evaluation.

The USABC continues to negotiate with other potential developers of advanced battery technologies and monitor the development of other advanced battery technologies. Through its Exploratory Technology Research Program, DOE continues to support the parallel development of promising high-risk battery and ultracapacitor technologies

with the potential to meet long-term goals. These technologies may be future candidates for USABC programs.

Fuel Cell Research and Development

Fuel cells that operate on nonpetroleum fuels could provide an alternative transportation propulsion system with nearly twice the fuel economy and significantly reduced emissions and noise compared with internal-combustion engines. The DOE Fuel Cells for Transportation Program is working closely with industry to develop commercially viable fuel cell propulsion systems for light-duty and heavy-duty vehicles. The program aims to advance fuel cell technologies from R&D through system optimization and scaleup to demonstration in cars, vans, and buses. The program has been developing and has plans to demonstrate the phosphoric acid fuel cell in an urban transit bus as a near-term application (by 1995). The program also has been developing the proton-exchange-membrane fuel cell as a midterm option for passenger vehicles and has been working to provide fuel flexibility by developing an advanced reformer and hydrogen storage system for onboard vehicle use. Proof-of-concept vehicles incorporating these advanced fuel cell technologies are expected by the year 2000.

During 1992 and 1993, the Department developed a National Program Plan for Fuel Cells in Transportation. This multiyear plan was based on a consensus for the development and commercialization of fuel cell vehicles formed at the two meetings of an ad hoc technical panel consisting of more than 50 representatives from industry, academia, and government.

Recent accomplishments under the Fuel Cells for Transportation Program include the following:

1. Completion of the first 2 years of a 3-year contract with the H-Power Corporation (Belleville, New Jersey) to design and build three fuel-cell-powered urban transit buses (Figure 1-8). At the end of 1992, H-Power had completed the major subsystem designs and had begun fabrication of the bus structure and the 50-kilowatt phosphoric acid fuel cell system. The first test-bed bus with a phosphoric acid fuel-cell/battery propulsion system will be delivered in early 1994, with two more to follow later in the year. All of these vehicles will be subjected to a rigorous test and evaluation program.
2. General Motors Corporation's Allison Gas Turbine Division completed the first phase of a 20-percent cost-shared project to develop the proton-exchange-membrane fuel cell as a complete power source sys-

1-8. Passenger bus powered by fuel cells.

tem for transportation applications. Allison and a team of subcontractors demonstrated the proof of feasibility for a 10-kilowatt, methanol-fueled, proton-exchange-membrane fuel cell system. The second phase of the project will involve design, fabrication, and testing of an advanced 30-kilowatt system. Proton-exchange-membrane fuel cell technology from several companies will be evaluated; the two with the most promise will be selected for further development and scale-up.

3. Under a 30-month cost-shared contract with DOE, Arthur D. Little, Inc., of Cambridge, Massachusetts, has completed phase I feasibility studies and identified preliminary concepts for an advanced reformer and hydrogen storage system. The reformer will be able to reform methanol, ethanol, or natural gas into hydrogen for use in transportation fuel cell systems. Work on Phase II, which involves designing, building, and testing a proof-of-concept ethanol reformer and an advanced hydrogen storage unit for onboard vehicle use, has begun.

Propulsion Systems, Vehicle Testing, and Evaluation

Concurrently with battery and fuel cell component technologies, DOE has been developing advanced electric powertrain (motors, controllers, and transmissions) technologies within the context of a total propulsion system matched to vehicle requirements. The overall goal is to develop vehicle systems that would be performance- and cost-competitive in the marketplace and that would be compatible with industry's marketing and production plans, the regulatory environment, and the transportation infra-

structure. The Propulsion Systems Program provides DOE and industry with the independent capability to test and evaluate emerging technologies and proof-of-concept vehicles in the laboratory and in the field under realistic conditions.

Through a series of projects conducted with the Ford Motor Company (Dearborn, Michigan) and General Electric Company (Schenectady, New York) since 1984, the Department has advanced the state of alternating-current propulsion technology to the point at which it can provide the basis for competitive electric vehicles as soon as an adequate battery technology becomes available. At the Idaho National Engineering Laboratory in 1992, DOE tested the Second Generation Single-Shaft Electric Propulsion (ETX-II) System test-bed vehicle, which was developed under the Propulsion Systems Program. The vehicle system included a sodium-sulfur battery and met all program goals, including a range of more than 180 kilometers at 88 kilometers per hour. In the final phase of this series of DOE-Ford-General Electric electric powertrain development projects, the Modular Electric Vehicle Program is modularizing the advanced alternating-current powertrain technology to facilitate mass production and to fit a broad range of vehicle sizes. Ford has successfully fabricated 10 75-horsepower (56-kilowatt) electric vehicle powertrains. Ford will deliver a test vehicle to DOE in 1993 for testing and evaluation. Ford will use the 75-horsepower (56-kilowatt) powertrain in its Ecostar electric van field demonstration program, with production likely in the mid-1990s.

In 1992 and 1993, the development of high-specific-energy capacitors for load leveling in electric vehicles continued to show significant progress. Tests performed at the Idaho National Engineering Laboratory on state-of-the-art capacitors indicated that spiral-wound, carbon-based devices are capable of an energy density of 2 watthours (7.2 kilojoules) per kilogram and 500,000 charge-discharge cycles. A Sandia National Laboratories-fabricated double-layer capacitor the size of a common D battery exhibited a total capacitance in excess of 1,000 farads; the carbon electrode exhibited a volumetric capacitance in excess of approximately 130 farads per cubic centimeter, and the energy density of the laboratory device was approximately 1.4 watthours (5.0 kilojoules) per kilogram. DOE placed a contract with Maxwell Laboratories (San Diego, California) and Auburn University (Auburn, Alabama) to develop bipolar, carbon-based ultracapacitors with an energy density of at least 5 watthours (18 kilojoules) per kilogram by 1995, which could be configured in a 100-kilogram unit to store 500 watthours (1.8 megajoules) of energy.

In August 1992, DOE initiated a 5-year cost-shared cooperative Hybrid Vehicle program with industry to develop and demonstrate hybrid propulsion systems for light-duty vehicles. These systems should satisfy EPA tier II emission standards, improve fuel economy by 100 percent compared with conventional gasoline-powered vehicles, and offer performance characteristics competitive with those of conventional vehicles in all other aspects. A \$138 million, 50-percent cost-shared contract with a team led by General Motors was signed in September 1993. The hybrid vehicle to be developed under this contract will combine recent advances in electric propulsion and small heat engines. A second development contract has been awarded to an industry team led by Ford Motor Company.

Electric Vehicle Field Operations

During 1992 and 1993, the Electric Vehicle Site Operator Program continued fleet tests and performance evaluations of more than 120 electric vehicles under typical operational conditions. More than 3 million miles (5 million kilometers) of electric vehicle operation have been accumulated. This cost-shared program currently includes 13 participants nationwide, including electric utilities and academic institutions working with state and local government agencies. The program has collected and disseminated a considerable body of data on engineering and operational characteristics of vehicles, batteries, and other components. As authorized by EPACT, DOE undertook planning in 1993 for a commercial demonstration program and a cost-shared infrastructure and support system development program that will help commercialize electric vehicle technologies.

Advanced Transportation Materials

The Transportation Materials Program supports the development of an industrial technology base in advanced structural ceramics, tribology, and nonceramic materials. In addition, the program makes sophisticated research facilities and technical expertise in advanced materials available to researchers in industry, universities, and other government agencies through the user-oriented High-Temperature Materials Laboratory. The goal of the program is to develop, in collaboration with industry and other elements of DOE's Transportation Technologies Program, cost-effective improved and advanced materials and as-

sociated processing technologies that would enable the development and engineering of transportation technologies that are more energy-efficient and that can use alternative fuels, including electricity.

Advanced Ceramics

Ceramic materials offer potentially useful characteristics, such as high-temperature capability, corrosion resistance, and light weight, but present a great technical challenge for automotive applications because of their inherent brittleness and manufacturers' difficulty in obtaining reliable mechanical properties. The Ceramic Technology Program conducts R&D on ceramic materials synthesis and processing, design methodology, and life prediction to improve the properties and performance of structural ceramics in order to meet the demanding design and operational requirements of high-temperature engine operation. As government and industry laboratories develop reliable ceramics, R&D is addressing approaches to reducing the cost of machining ceramic components and improving their performance. For the midterm, ceramic components could be introduced into current automotive engines to improve efficiency and to facilitate the use of alternative fuels. These applications would provide the U.S. automotive and ceramic industries with the experience needed to bridge the gap between production of limited-quantity prototype components and the mass production of ceramics for conventional and advanced automotive engines. For the long term, ceramics for high-temperature applications would promote the development of advanced gas turbine and diesel engines.

The following are recent major accomplishments of the Ceramic Technology Program:

1. Achievement of a dramatic increase in the mean tensile strength of silicon nitride specimens (from 190 megapascals in 1980 to 650 today), a reduction in the variability of specimen tensile strengths, and a thousandfold improvement in high-temperature fatigue life
2. Development of two new brazing alloys for joining silicon nitride to superalloys, representing major advances over previously available brazing alloys
3. Initiation of a new program in ceramic machining technology development (DOE, with the support of ORNL identified and prioritized the major cost drivers for ceramic machining, completed a program plan, and initiated new industry contracts to reduce the cost and improve the quality of ceramic machining)

4. Development of a ceramic coating to protect silicon nitride ceramics from contact stress damage and corrosion by salt (the coating, developed by GTE Laboratories of Waltham, Massachusetts, consists of several graded layers of ceramic and provides excellent adhesion and a low coefficient of friction up to 1,000°C)
5. Scaleup of the Sullivan process, a unique, potentially low-cost process for making silicon nitride components from organic liquid precursors, from a laboratory reactor to a pilot-scale reactor (test bars were produced by the Sullivan Mining Corporation of Greenwood, Indiana, and evaluated by ORNL)
6. Demonstration at ORNL of the feasibility of fabricating sintered, reaction-bonded silicon nitride in a microwave oven, using a single nitridation-sintering step and low-cost raw materials
7. Continued development of a new generation of high-performance, in-situ-toughened silicon nitride in a program involving the AlliedSignal Aerospace Company (Torrance, California), the University of Michigan, Ann Arbor; and ORNL

Tribology: Friction, Wear, and Lubrication Research

The severe operating environments expected for advanced heat engines pose friction, wear, and lubrication problems that may outweigh expected benefits of higher thermal efficiency. In addition, alternative fuels' incompatibilities with lubricant formulations lead to lubricant failure and engine breakdown. The Tribology Program conducts friction, wear, and lubrication research to reduce energy losses inherent in moving engine parts and to avoid high levels of wear that contribute to inefficiencies and engine failure. The program is developing improved and novel high-temperature lubricants and lubricant delivery systems and surface engineering and coating techniques to produce hard surfaces and intrinsically lubricous surfaces and to improve friction and wear properties of engine parts. The program has also developed techniques to mitigate friction and wear of lubricated and unlubricated ceramics; these techniques are required for the commercialization of advanced heat engine concepts.

Selected program accomplishments during 1992 and 1993 included the following:

1. For engine evaluations, preparation at the National Institute of Standards and Technology (NIST) of pilot-plant quantities of a superstable lubricant that is capable of surviving for a minimum of 7 minutes at top ring reversal temperatures of 425°C (independent cooperative R&D with Caterpillar, Inc., and the Akzo Chemical Company, Dobbs Ferry, New York, has also led to development of high-temperature liquid lubricants that have undergone successful evaluation in engine tests at Caterpillar and the Cummins Engine Company)
2. Development of a high-temperature liquid lubricant for advanced heat engines that successfully performed at 375°C in a 100-hour engine test (compared with 250°C for conventional engines)
3. Conduct of a workshop involving additive, lubricant, and engine manufacturers to address automotive industry needs (the workshop resulted in the initiation of a base lubrication program at NIST that will provide the possibility of achieving 1-million-mile (1.6-million-kilometer) durability for advanced diesel engines through resolution of friction and wear problems)
4. Initiation of a cooperative research and development agreement with the Harrison Radiator Division of General Motors Corporation (Lockport, New York) to investigate surface modification of material pairs for HFC-134a (the alternative refrigerant to dichlorodifluoromethane, a CFC (CFC-12), which is used extensively in mobile air-conditioning compressors)

Materials Technology—Metals, Polymers, and Composites

The Materials Technology Program focuses on developing lightweight materials for vehicle structures and materials compatible with alternative fuels. Lightweight materials not only improve fuel economy in conventional gasoline engine vehicles but also are critical in enabling electric vehicles to achieve the range and responsiveness required to make them acceptable to the U.S. consumer. Processing and manufacturing techniques are being developed to lower the cost of high tech lightweight, high-strength materials, such as polymer and metal matrix composites and ordered intermetallic and other alloys, and to make them competitive with conventional sheet steel on the bases of cost and performance. Technologies for recycling an ever-increasing amount of lightweight materials from automobiles are also needed, because the entire polymeric fraction of shredded automobiles currently goes into landfill sites. Improved processing technology will enable vehicle manufacturers to design 30- to 50-percent lighter, more fuel-efficient vehicles with the structural integrity and safety of today's heavier cars.

In developing the lightweight materials program, DOE conducted several workshops and received extensive input from the three major U.S. automakers and industrial suppliers of materials. DOE initiated R&D on lightweight materials in 1993, with the focus on two categories of materials identified as priorities by the automotive companies: (1) metals and alloys and (2) polymers and polymer matrix composites. Two R&D projects were initiated in the metals area and one in the polymers area. These efforts were coordinated with industrial partners either individually or as a consortium of auto companies.

The compatibility of materials and alternative fuels, primarily alcohols and natural gas, affects the engines and vehicles themselves as well as fuel production and infrastructure. DOE is developing alternative-fuel-compatible materials to allow more optimal operation of current engines. The Materials Technology Program is targeting new emission control system materials to enable the next generation of high-efficiency heat engines to meet clean air requirements. These materials include nitrogen oxide-reducing catalysts for energy-efficient lean-burn engines, low-temperature methane-oxidizing catalysts (for compressed-natural-gas-fueled vehicles), and catalysts that are not inactivated by methanol-containing fuels. Program accomplishments during 1992 and 1993 included development of industry-guided multiyear R&D plans for fuel and emission system materials programs; in collaboration with a U.S. automaker, adaptation of an advanced metal-forming technique commonly used in the aircraft industry to the forming of complex automotive components for a current-model vehicle, as well as demonstration of the technique's cost-effectiveness; and initiation of a cooperative research and development agreement with industry to evaluate emissions control catalytic materials for alternative-fueled vehicles.

High Temperature Materials Laboratory

For the Transportation Materials Program to be effective, state-of-the-art research facilities for materials synthesis, processing, and characterization are necessary. DOE operates the High Temperature Materials Laboratory at ORNL as an industrially oriented user facility available to U.S. companies and academic researchers conducting materials R&D. The High Temperature Materials Laboratory furnishes the state-of-the-art materials R&D facilities and materials characterization instrumentation necessary to conduct modern materials science and engineering R&D. The laboratory consists of six user centers for materials analysis, high-temperature mechanical properties, high-temperature x-ray diffraction, physical properties, ceramic

specimen preparation, and residual stress measurements. Users may carry out research that produces open-literature publications with an ORNL coauthor at no charge and may also conduct proprietary research at the facility under cost recovery agreements.

Use of the user centers has been growing. The High Temperature Materials Laboratory has executed a total of 118 nonproprietary agreements (62 university and 56 industry) and 28 proprietary agreements (2 university and 26 industry) and has been accessed by researchers from 66 universities, 82 industrial companies, and 6 other government facilities. A new x-ray residual stress research facility became operational in 1992, and it is receiving heavy industrial use.

INDUSTRIAL TECHNOLOGIES

Introduction

The President's technology policies create both an opportunity and an obligation for DOE to sharpen its strategic focus on American industrial competitiveness through improved productivity and waste reduction. International competitiveness depends less and less on traditional factors, such as access to natural resources and cheap labor; rather, it depends on continuous generation of new technological innovations and rapid transformation of those innovations into commercial products the world wants to buy. Modern production systems also make much more efficient use of energy and materials, with products that are competitive in cost and quality with the best in the world. At the same time, a massive trend in U.S. industry toward waste reduction will reduce future waste disposal and pollution control costs, and itself create substantial opportunities for equipment and technology exports.

Although the oil crisis of the early 1970s spurred U.S. industry to increase its energy efficiency, the potential for further improvement is significant. In 1992, the industrial sector accounted for 37 percent of all U.S. energy consumption—30.6 quads (32.3 exajoules) out of a total of 82.4 quads (86.9 exajoules). In addition, industry used about 1.5 quads (1.6 exajoules) of energy from the wastes it produced. Five large, energy-intensive industries—chemicals, petroleum, primary metals, pulp and paper, and stone, clay, and glass—are responsible for approximately two-thirds of industrial-sector energy use and for approximately three-quarters of all manufacturing industry energy use (Figure 1-9). The energy efficiencies of many

processes in these five and other industries are still lower than those in some developed countries and well below theoretical limits. The ability of industry to improve its energy efficiency, productivity, and competitiveness is tied to the availability of appropriate technology and increased investment in modern, energy-efficient equipment.

The projections made by the Energy Information Administration in its *Annual Energy Outlook 1994* indicate the magnitude of the potential savings. The reference case projection is that industrial energy use in 2010 will be close to 41 quads (43 exajoules). However, if newer technologies and processes are adopted, EIA estimates that a cumulative total of 59 quads (62 exajoules) could be saved by 2010. This would require a continued decrease in the overall energy intensity of the industrial sector. To achieve this reduction, industry will have to improve its energy efficiency significantly, which will require substantial investments in advanced technological R&D by government and industry and widespread adoption of the most efficient equipment and practices. Although the investment required by industry will be substantial, the payback in profits and increased international competitiveness should more than compensate.

Scope of Program

The Office of Industrial Technologies (OIT) sponsors the development of advanced technologies that can capitalize on opportunities to improve the energy efficiency, productivity, and competitiveness of the industrial sector. To ensure that DOE's activities are well balanced and will increase the Nation's international competitiveness and the quantity and quality of U.S. jobs, OIT focuses on technologies and processes that could reduce energy demand, facilitate the use of alternative energy supplies, and reduce infrastructural barriers while minimizing environmental impacts and costs (Figure 1-10).

OIT's goals are firmly rooted in key industrial sector goals; improve energy efficiency and fuel flexibility in the industrial sector, encourage cost-effective measures to reduce energy costs and reduce industrial waste generation, and increase use of plant- and consumer-generated wastes as process feedstocks. To help the Nation achieve these goals, OIT attempts to identify the barriers to increased industrial energy efficiency. Conducting activities to overcome these barriers is the primary focus of OIT R&D and technology commercialization efforts.

In pursuing these goals, OIT relies on market forces to encourage the use of new, more efficient technology. The

1-9. Industrial energy use by industry, 1991.

office also seeks to remove barriers that prevent equal treatment of investments in energy productivity and hinder the transfer of DOE technologies and information to industry. OIT leverages Federal funds by actively involving industry in R&D activities and also by collaborating with other Federal and state agencies in areas of mutual interest.

There are eight major R&D areas within OIT that address energy demand: materials processing, separations, sensors and controls, biological and chemical technology, enabling materials, combustion, process heating and cooling, and cogeneration. These programs conduct R&D efforts to develop energy-saving and fuel-flexible technologies in the near, mid-, and long terms. Opportunities addressed include processes within specific industries (for example, steel), as well as processes that cut across industries (for example, separations).

Materials Processing

The high-temperature materials-processing industries—iron and steel, aluminum, and glass—involve some of the most energy-intensive processes found in the industrial sector. The objective of OIT's Materials Processing Program is to increase the energy efficiency of the major processes within these industries. In cooperation with industry, OIT is working to combine or eliminate energy-intensive unit operations, improve processing to reduce energy demand and enhance productivity, and reduce manufacturing costs to improve competitiveness. Materials Processing Program R&D activities fall into three primary categories:

1-10. Visual depiction of the challenges facing the U.S. industrial sector: expanding trade deficit, high levels of energy use, and environmental emissions.

the Metals Initiative, process electrolysis, and other research, which includes metal casting, glass, and refractories.

Metals Initiative

The Metals Initiative, mandated by Public Law 100-680 (the Steel and Aluminum Energy Conservation and Technology Competitiveness Act of 1988), is the largest single component of the Materials Processing Program. Under this initiative, OIT supports research in direct steelmaking, spray forming of sheet steel, superplastic steel processing, and alumina reduction. The direct steelmaking effort is aimed at developing an environmentally benign, coal-based steelmaking process that will decrease energy consumption and reduce capital costs through elimination of process steps.

The direct steelmaking project was the major focus of the Metals Initiative in 1993, with the American Iron and Steel Institute successfully completing pilot trials of a two-zone horizontal smelter (Figure 1-11). The smelter produced liquid metals with various carbon contents with an operation consisting of a reduction zone and an oxidation zone. The direct steelmaking project has the potential to reduce energy consumption by 20 percent, reduce operating costs by 10 percent, and reduce capital costs significantly. To further the commercialization of this process, the Institute completed a feasibility study of a 350,000-ton (317,515-metric-ton) demonstration plant.

OIT continued to support the development of superplastic steels by Lawrence Livermore National Laboratory and several industrial participants. Potential energy savings from use of superplastic steel are at least 0.01 quad

1-11. Jointly sponsored direct steelmaking project between the American Iron and Steel Institute and DOE to develop a smelting process for directly producing liquid steel using coal instead of coke, as required by the conventional coke oven/blast furnace/oxygen steel-making process.

(0.01 exajoule) per year. In addition, superplastic steel could reduce manufacturing costs by 17 percent. During 1993, Lawrence Livermore National Laboratory verified its computer simulations of superplastic forming of simple shapes.

In addition, OIT continued to support a direct strip casting project, which is being conducted by Armco, Inc. (Middletown, Ohio), for the development of steel sheet and strip products. The replacement of continuous slab casting, slab reheating, and hot rolling facilities with a direct strip casting process could save \$50 per ton of steel produced and 0.2 quad (0.2 exajoule) in energy per year. During 1993, major modifications to the caster resulted in greater strip thickness and improved quality. A heat transfer and solidification model was also completed. Other ongoing projects include electrochemical dezincing of steel scrap and rapid analysis of molten metals using laser-produced plasmas.

Other projects completed in 1993 were the development of an online process control system for cupola furnaces and an improved expendable-pattern casting process. At the end of 1993, DOE began a new project with the American Iron and Steel Institute to develop sensor and control system technology for the steel industry. This project consists of six efforts to address various phases of steelmaking, from primary steelmaking through finish

processing. The estimated energy savings potential is 14 trillion British thermal units (Btu; 15 quadrillion joules) per year.

Three Metals Initiative projects are under way with the aluminum industry. Under the OIT stable cathode project, the Reynolds Metal Company (Richmond, Virginia) is working with the Great Lakes Research Corporation (Briarcliff, New York) to develop titanium diboride-graphite cathodes for electrolyzing aluminum in commercial reduction cells. The Kaiser Aerospace and Electronics Corporation (Mead, Washington) joined the team and helped Reynolds complete the design for retrofitting a 77,000-ampere prebake alumina reduction cell. In 1993, the new cathodes were produced and the first test cell was started up. The new cathode technology has the potential to save 0.1 quad (0.1 exajoule) per year. In addition, two new projects were initiated in 1993: development of a more energy-efficient pressure calciner for alumina and development of a cost-effective spray-forming technology to replace ingot casting of aluminum.

Process Electrolysis

Aluminum, magnesium, chromium, manganese, chlorine, and other industrial materials are produced by energy-intensive electrolytic reduction processes. Industry uses more than 1.1 quads (1.2 exajoules) of energy annually in aluminum and magnesium reduction and chlorine production. The energy efficiencies of these processes are typically less than 50 percent. To achieve significant energy savings, there is a need for better understanding of the processes, the electrolytes, the electrodes, the cell lining materials, and the points of energy loss in electrolytic reduction cell operation. Currently funded projects relating to production of primary aluminum have the following goals: savings of 0.24 quad (0.25 exajoule) by reducing the anode-cathode gap, reduction of production costs by 20 percent, reduction of carbon dioxide generation by 192 million tons (174 million metric tons), and elimination of carbon tetrafluoride compounds.

In 1989, OIT initiated a low-temperature-bath project with the Aluminum Company of America (Alcoa) at Alcoa Center, Pennsylvania, to develop an energy-efficient alumina reduction cell. The object of this effort was to develop a retrofit cell design that uses cermet anodes and low-temperature electrolyte to reduce alumina to aluminum, but requires 20 percent less specific energy. Alcoa has submitted a plan for a 2-year continuation to resolve the technical and economic issues that have developed as a result of the use of high-acid baths. The 100-hour bench

test completed in 1992 indicated that tests of 200 hours are required to verify previous results and determine boundary conditions for operation.

Ceramic manufacturers completed evaluations of methods to produce the intricate anode shapes that are required for pilot tests of cells and anode materials. Ultimately, the anodes will be used in conjunction with Alcoa's low-temperature-bath approach. In addition, the Massachusetts Institute of Technology (Cambridge) completed a 1-year investigation of possible metal anodes in modified commercial cryolite baths for aluminum production.

The Dow Chemical Company (Midland, Michigan, and Midland, Texas) continued development of inert anodes for magnesium cells to investigate the feasibility of a fluidized-bed reactor for electrowinning of copper from leachates with Metalor (North Attleboro, Massachusetts; contract being negotiated) and EMEC (New Kensington, Pennsylvania) and Rhône-Poulenc (Princeton, New Jersey).

Other Research

Metal Casting

In recent years foreign competition has severely threatened the competitiveness of the U.S. metal-casting industry, which produces essential components for transportation equipment, manufacturing, and piping. To meet this challenge, Congress passed the DOE Metal Casting Competitiveness Research Act of 1990 to establish an industry-cost-shared research program to improve the competitiveness and energy efficiency of U.S. metal casting. Consistent with the legislation, OIT prepared a plan incorporating the recommendations of the DOE Metal Casting Industrial Advisory Board and input from representatives of trade associations and professional societies and other industry experts. The University of Alabama (Tuscaloosa), and the University of Northern Iowa (Cedar Falls), designated as National Metal Casting Research Institutes, began to research priority metal casting areas in 1992. During 1993, these two institutions continued work on ultrasonic testing of castings, predictions of conditions causing defects in ferrous castings, and development of a method of using shock-wave lithotripsy for removing cores from investment castings. DOE issued a competitive solicitation in 1992 to establish national metal-casting research institutes in regions of the United States where the industry is concentrated. As a result, DOE is establishing four additional National Metal Casting Research Institutes.

Glass

A 1988 study of energy consumption in the U.S. glass industry revealed that glass-melting technologies are prime targets for energy savings. The melting and refining steps consume 54 percent of all energy used to manufacture glass. Because glass refining is the rate-limiting element, development of an advanced rapid glass refiner would increase investment in advanced glass melters. Energy savings could range from 0.01 to 0.05 quad (0.01 to 0.05 exajoule), depending on the mode of application, retrofitting, and use in conjunction with a rapid glass melter.

The Vortec Corporation (Collegeville, Pennsylvania) and the Certainteed Corporation (Blue Bell, Pennsylvania) are cost-sharing the development of a rapid glass refiner that could be retrofitted to existing glass melters or used with a rapid glass melter. In 1993, Vortec built and operated a rapid—750-pound (340-kilogram)-per-hour—glass refiner and produced container glass from virgin batch material in less than 2 hours.

Refractories

Industry uses refractories as enabling technologies for two basic applications: process containment with hot-face-exposed materials and insulation to reduce heat loss, prolong equipment life, and provide acceptable working conditions. Industry derives increased productivity and improved product quality, in addition to energy savings, when properties of refractories are improved.

OIT supports two projects to develop high-temperature insulating materials that could reduce heat loss through furnace linings by 10 to 30 percent (0.06 quad, or 0.06 exajoule). Alcoa (Pittsburgh, Pennsylvania) is evaluating approaches for producing alumina aggregates for use in fabrication of lightweight refractories, and Manville Sales Corporation (Littleton, Colorado) is investigating improved, high-performance refractory fiber composition with a high-service-temperature range of 2,600 to 3,000°F (1,400 to 1,700°C). Both projects have continued with phase II. Manville is evaluating new refractory fiber compositions, expanding the data base under development, producing new fibers at laboratory and pilot scales, and selecting candidate fiber compositions for industrial tests. Alcoa has produced kilogram quantities of lightweight refractory aggregate materials at laboratory scale, determined performance of the new materials, and estimated commercial process economics. Alcoa will complete phase II with the pilot-scale evaluation of hardware to produce the low-density aggregate.

Separations

Separation technologies are vital in the production of petroleum products (for example, fuels and petrochemical feedstocks), paper, inorganic and organic materials (for example, chlorine and polymers), food products, textiles, and fertilizers. Innovative separation technologies offer major crosscutting opportunities for energy savings and productivity gains in industrial processes. Distillation, evaporation, drying extraction, and gas absorption and adsorption are the critical, energy-intensive processes used to separate one or more components from a solution or mixture. Most of these processes use more than 50 times as much energy as is thermodynamically required. Distillation and evaporation alone consume 2.6 quads (2.7 exajoules) per year, and industrial drying uses another 1.8 quads (1.9 exajoules) per year. Advances in separations would enhance the applications of next-generation technologies, such as bioprocessing from low-volume specialty chemicals to higher volume commodity chemical markets.

Research on the recovery of black liquor, a byproduct of the pulping process in the paper industry, continued in 1993. The University of Florida at Gainesville completed experimental determinations of black liquor physical properties and will begin incorporating the results into software for predicting liquor physical properties from liquor composition. Research at the Institute of Paper Science and Technology (Atlanta, Georgia) on spray systems continued; researchers completed spray tests and comparisons of standard and alternative nozzles and began designing an alternative delivery system. Construction and installation of the pulse combustion gasifier, developed by Manufacturing Technology Conversion International (Columbia, Maryland) is under way at the Weyerhaeuser Paper Company pulp mill in New Bern, North Carolina. Shakedown tests are slated for fall 1993.

In other paper research during 1993, the Institute of Paper Science and Technology (Atlanta, Georgia) continued work on two-sided impulse paper-drying technology, a revolutionary process that may achieve water removal rates 100 to 1,000 times faster than conventional rates. Evaluation of ceramic-coated rolls in conjunction with an extended nip press on a Beloit pilot machine was initiated.

R&D on combustion-recovery boiler modeling (code development) continued with the Institute of Paper and Science Technology, the University of British Columbia (Vancouver, British Columbia, Canada), the Abo Akademi

of Finland, Oregon State University (Corvallis), and T. M. Grace Company. Development of a 3-dimensional flow model will incorporate release of sulfur and sodium into the furnace model and the char bed and improved combustion models into the fixed-field models. Various submodel validation efforts will begin in the fall of 1993.

The Dairy Research Foundation (Rosemont, Illinois) completed freeze-concentration studies and market analysis for processing dairy products, such as milk and whey. An alternative to thermal concentration processes, freeze-concentration is energy efficient and prevents product degradation. William R. Trutna (Austin, Texas) and the University of Texas at Austin have completed initial pilot-plant testing of the Trutna Tray, a unique distillation technology that has higher energy efficiency and better performance than conventional distillation.

Another integral research area of the Separations Program is improved membrane systems. The State University of New York at Syracuse evaluated materials for potting hollow-fiber ion-exchange membranes into a module. BP America Research (Warrensville, Ohio) has been pilot-testing a novel hybrid distillation-facilitated transport membrane system for the separation of propane and propylene; a demonstration plant at a BP oil refinery became operational in late 1992. Air Products and Chemicals, Inc. (Allentown, Pennsylvania), completed the design, fabrication, and testing of spiral-wound active-transport membrane modules for ammonia separation. Other areas of research included piezoelectrically active membranes, ceramic membranes, and polyphosphazene membranes.

DOE addressed feedstock flexibility for the chemical plant of the future by supporting research in alternative feedstocks. Up to 1.0 quad (1.05 exajoules) of petroleum-based feedstocks could be displaced with dedicated forestry and agricultural resources in the manufacture of high-volume, nonenergy chemical products. The objectives of this research include enhancing energy security by displacing petroleum-based chemical feedstocks, improving environmental quality by promoting carbon recycling and environmentally acceptable chemical processing and bioprocessing, expanding the global competitiveness of U.S. chemical industries through value-added products and processing, revitalizing the domestic rural economy, and reducing farm program costs. Work completed in 1992 included initial engineering, economic, and market assessments to prioritize targets, to identify industrial partners to draft a strategic plan, and to prepare a technical resource document for biomass-to-chemical technologies.

Sensors and Controls

Use of improved sensors and controls is a key method for increasing the energy efficiency and productivity of industrial plants. Plant operators and engineers need sensors in many industrial applications to provide them with better information about their processes so that they can improve total plant control of processes and quality. The growth of automation in industry relies heavily on sensor measurement of process variables and on the development of process control methods. The situation is complicated by the extreme diversity of industrial applications and environments (for example, high temperature, pressure, corrosive materials) hostile to industrial sensing equipment. Existing instrumentation cannot fully monitor many industrial processes (for example, papermaking and steel-making).

Advanced sensor and control technology could reduce energy use and reduce the costs of production by decreasing labor costs, reducing wastes, and increasing production. Development of new sensors is extremely industry and process specific and carries a high risk of economic failure for any single industry or sensor manufacturer. A key objective of the Sensors and Controls Program is to integrate the design of sensors and control systems with the materials-processing, pulp and paper, food-processing, and chemicals industries and with the petroleum-refining plants of the future.

In 1993, DOE continued to conduct research to support the materials-processing industry. Researchers at ORNL completed the bench-scale development of an online composition sensor and built, installed, and began the operation of a prototype sensor in a commercial magnesium cell. Energy and Environmental Research Corporation (Irvine, California) also completed the field test of a glass temperature sensor for improved glass quality control. The Sensors and Controls Program also assisted NIST with its intelligent-processing project for rapidly solidified metal powders.

The Sensors and Controls Program also continued to support R&D for the pulp and paper industry. Laboratory data verification began at the Babcock and Wilcox Company (Alliance, Ohio) for an ultraviolet fluorescent sensor that measures the concentration of lignin in wood pulp. The program initiated a project to develop an online viscosity sensor for better control of black liquor recovery boilers. The Institute of Paper Science and Technology completed an offline integration and material balance program interface for the modular dynamic thermomechanical pulping model and continued R&D on operating variables

and pulp varieties for an on-machine sensor and control system.

In 1993, the Sensors and Control Program supported R&D applicable to the food-processing, chemical, and petroleum industries. Work on an on-farm ammonia sensor at the Georgia Institute of Technology (Atlanta) included laboratory testing, fabrication of an environmental test chamber, and demonstration of an absorption and interferometric device. Southwest Research Institute (San Antonio, Texas) completed the field test of a hydrogen transient nuclear magnetic resonance sensor for determining real-time moisture content of corn wet-milling process streams. The development and field tests of a planar waveguide sensor for nonaqueous distillation systems were also completed. At the University of Tennessee at Knoxville, laboratory testing of the prototype Raman composition sensor for distillation processes was completed, and field tests were initiated at the Tennessee Eastman Corporation (Kingsport, Tennessee).

Biological and Chemical Technology

The prospects for new technology development depend on the ability of process scientists and engineers to understand and manipulate the chemical mechanisms and engineering principles that are the foundation of all process operations. All industrial processes have a common set of basic requirements that include blueprints for fabricating products, controlling algorithms, and operating rules for various unit operations, all of which must be understood in the context of energy efficiency, economic competitiveness, and environmental impact. This understanding, combined with cost-effective process engineering within the private sector, pre-positions these technologies so that industry may use them as market conditions warrant.

The mission of the DOE Biological and Chemical Technology Program is to provide experimental evidence of the technical and economic feasibility of advanced chemical and biological concepts that can improve the energy use, operation efficiency, and environmental soundness of U.S. industrial process operations. Toward this end, the Biological and Chemical Technology Program sponsors efforts to apply the fundamental principles of biological and chemical sciences to make or modify products and to apply engineering principles to develop cost-competitive process concepts. The goals and objectives of the program are met through collaborative research ventures involving U.S. industries, universities, and national laboratories.

In 1993, the program drew nearly \$6 million in cost-sharing from more than 50 different corporations.

The research efforts of the Biological and Chemical Technologies Research Program are focused on technology development for use by the chemical and allied products and the petroleum-refining industries. Necessary first steps in realizing the potential of advanced chemical and biological technologies involve developing new and improved catalysts and biocatalysts that improve reaction rates, yields, and selectivities, combined with a rational design approach that reduces the time and effort necessary to identify, test, and commercialize new catalysts and biocatalysts. In biotechnology, similarly, a necessary complement to the development of new biocatalysts is the engineering of bioreactor systems that maintain high productivities and yields. Currently, these are the cornerstone activities within the program.

Through 1993, research accomplishments include the following:

1. Development of a surface chemistry model for the industrially important vanadyl pyrophosphate catalyst by Pacific Northwest Laboratories. This model allows process engineers to evaluate new catalyst designs to improve the process chemistry and product yields for this reaction.
2. Development of an electrochemical approach to effectively convert food waste materials, such as fats, into high-value chemicals by Tulane University (New Orleans, Louisiana). This approach could increase the yield of high-weight polyunsaturated hydrocarbons, which is not now possible through conventional technology.
3. Development of a user-friendly desktop software package that facilitates technoeconomic analysis of advanced biological and chemical process schemes by researchers at the Jet Propulsion Laboratory (Pasadena, California).
4. Synthesis of a new class of environmentally friendly chemical polymers, resulting from research by the California Institute of Technology (Pasadena) in protein and enzyme engineering.
5. Construction of a biomimetic model by Sandia National Laboratory used to guide laboratory investigations in development of an enzyme for binding carbon dioxide. This capability is the first step in developing a catalyst for the direct conversion of carbon dioxide to chemicals.
6. A revolutionary breakthrough in the ability of microorganisms to better utilize oxygen, which greatly enhances biological productivities and yields. Pre-

liminary investigations at ORNL in the design of new bioreactors has demonstrated product yield improvements of 50 to 90 percent compared with conventional fermentation technology. This development helps to advance biotechnology from low-volume, high-cost products toward high-volume, low-cost products and has led to a CRADA between Dow and ORNL for application of the bioreactors in a major Dow chemical process line.

7. Research in the design of enzymes for use in organic media that led to a project with Allied Signal Corporation (Des Plaines, Illinois) for the potential development of a new chemical product line related to biosensors. A CRADA was signed between Idaho National Engineering Laboratory and Simplot, Inc., (Pocatello, Idaho) for continued development of a biological process to solubilize phosphate ore.

The Biological and Chemical Technologies Program will continue to build upon these technological accomplishments to improve industry energy efficiency, feedstock flexibility, and market competitiveness. Ultimately, the R&D sponsored by the program will provide improved biological or biomimetic catalysts for industry operations, validated process engineering and operation models to guide engineering development efforts, and process design concept schematics to guide process development activities.

Through the last 5 years and approximately \$21 million in research investments, the program has contributed to the development of five new companies that now employ more than 400 American workers and account for more than \$60 million in annual salaries and benefits. In addition, program-supported research has resulted in 14 patents (with 4 more pending) and numerous technical awards from DOE, various professional organizations, and private corporations. In 1993, more than 40 U.S. companies collaborated and participated in the program's R&D activities, contributing more than \$3 million in corporate funds to match the \$5.1 million in program funds.

Enabling Materials

Advanced materials can save significant energy by enabling systems to operate more efficiently with minimal environmental impact, while increasing service lives and reducing life-cycle energy costs, downtime, and capital costs. The development and adoption of new heat-, wear-, and corrosion-resistant metals, ceramics, and composites with

superior strength and toughness in severe environments promises to make U.S. industry more competitive by increasing productivity and allowing it to compete more effectively in the international market. Use of continuous-fiber ceramic composites, which are lighter, stronger, tougher, and more corrosion resistant at high temperatures than other materials in the industrial applications that DOE has identified to date, can potentially save 1.1 quads (1.2 exajoules) per year and reduce emissions of nitrogen oxide by 0.6 million tons (0.5 million metric tons).

It is widely recognized that although the United States is the world leader in basic research in materials, inadequate attention has been paid to the synthesis and processing needed to adapt basic technology to industrial applications. DOE therefore supports applied R&D on enabling materials, as well as applications engineering, to adapt the materials and processing methods to identified energy-saving uses. These activities are performed in partnership with industrial producers and users of materials.

Continuous-Fiber Ceramic Composites

In 1990, the Office of Industrial Technologies embarked on a 10-year program to develop and demonstrate, methods for processing continuous-fiber ceramic composites (CFCCs) into shapes representative of the geometries needed for potential applications in, for example, heat engines and chemical processes. The office initiated research at ORNL and at selected universities on testing methods, nondestructive evaluation of composite materials, fiber interface, and investigations of residual stress and stress reduction.

In 1992, OIT contracted with 10 industry-led teams, totaling 42 industry, university, and national laboratory participants, to begin R&D of CFCC-processing methods. Since then, the researchers have made significant strides. Researchers on the CFCC team led by the AlliedSignal Aerospace Company (Torrance, California) and Caterpillar, Inc., have designed a nonlubricated CFCC valve guide that eliminates 25 percent of the particulate emissions of a diesel engine. Alzeta Corporation (Santa Clara, California) researchers have designed and tested a high-output CFCC component that doubles the efficiency of radiant burners in drying applications. Researchers at Amercom, Inc. (Chatsworth, California), have achieved the ability to create functionally gradient material layers (from silicon carbide to alumina) in a single step. The Babcock and Wilcox Company (Lynchburg, Virginia) team reduced the number of CFCC processing steps by half while reducing

material porosity by 60 percent. The approach that was developed should be ideal for the oxide-based composite system. The Dow Chemical Company team increased their processing rate for material production while increasing material quality. The Dow Corning Corporation (Midland, Michigan) team increased the reliability of a CFCC by 40 percent while significantly increasing the material's strength using a technique called polymer impregnation and pyrolysis. The E.I. du Pont de Nemours & Company (Wilmington, Delaware) team identified CFCC components that would increase the power generation efficiency of a coal-fired powerplant from 35 to 47 percent, with a 25-percent reduction in emissions. Researchers on the DuPont Lanxide Composites, Inc. (Newark, Delaware), team increased the conductivity of their material (a silicon carbide fiber-reinforced alumina matrix composite) by 25 percent. General Electric Company researchers increased the strength of their material (Toughened Silcomp) by 50 percent by changing their preform fabrication process. The Textron Specialty Materials, Inc. (Lowell, Massachusetts), team increased their CFCC material's strength by 30 percent while increasing the material processing rate by a factor of 10.

Advanced Industrial Materials

For the Advanced Industrial Materials Program, 1993 was a year of continued technical achievement, increased industrial cooperation, and recognition of the accomplishments of investigators. By the end of 1993, industrial partners were active in every area of the program, with more than 100 companies working with the researchers in the program. Cooperative research and development agreements (CRADAs) were established or are being discussed for every project.

Research on intermetallic alloys at ORNL and Los Alamos National Laboratory (LANL) has eliminated the technical barriers to the use of these very-high-temperature materials. DOE is performing cooperative work with industry to engineer specific applications. Three CRADAs, involving ORNL and three U.S. companies, are aimed at the use of nickel aluminides as high-temperature structural materials. Another CRADA, between LANL and the only U.S.-owned producer of silicon carbide whiskers, is aimed at the development of composites of these whiskers with molybdenum disilicide for a new generation of high-temperature heating elements and for structural uses. Work continues on processing of nickel, titanium, and iron aluminides needed for practical use.

The Advanced Industrial Materials Program redirected its work on chemically specific thin films, silica aerogels,

conducting polymers, magnetic processing of polymers, and biomimetic thin films in 1993 to provide the nucleus for an enhanced effort in engineered porous materials. These materials can produce a wide variety of industrial energy savings and productivity improvements.

A coordinated effort among researchers at ORNL, LANL, Sandia National Laboratories, and Lawrence Livermore National Laboratory, in cooperation with several university and industrial partners, has advanced understanding of the basic mechanisms controlling the synthesis and properties of a wide variety of composites, including fiber-reinforced silicon carbide and titanium diboride, oxide and carbide composites bonded with intermetallic alloys, and composites formed by infiltration of a reactive molten metal. This effort will provide basic knowledge of composite formation, improve the chemical vapor deposition and infiltration processes, and make a variety of low-cost, net-shape structural materials with superior properties available to industry.

Microwave processing research at ORNL and LANL resulted in energy-saving methods for sintering oxide ceramics and the invention of a variable-frequency-microwave furnace, which has been licensed to industry and is on the market. Work is now being performed at both of these national laboratories to develop microwave methods for saving energy and increasing productivity in the processing of glass ceramics, the curing of fiber-reinforced thermosets, and the production of oxide reinforcing fibers.

DOE completed an assessment of the needs and opportunities for new or improved materials in the pulp and paper industry in 1993. National laboratory staff and representatives of the industry, along with their equipment suppliers, have identified many specific needs. The Department will use the assessment, which is intended as a test case for such studies in other industries, for program planning.

Combustion

OIT's combustion programs encompassed both fundamental and equipment development activities. The Industrial Combustion Technology Program focuses on the fundamentals of combustion. Its goals are to identify and study new ideas and concepts that can improve combustion efficiency and reduce emissions. The Industrial Combustion Equipment Program develops and demonstrates high-efficiency, low-emission combustion equipment for use by industry.

Industrial Combustion Equipment

Researchers at Sandia National Laboratories developed a new optical technique, called degenerate four-wave mixing spectroscopy, for measuring combustion species, and *Science*, the official publication of the American Association for the Advancement of Science, honored the achievement. The technique, which uses three low-power lasers, can be used to measure individual combustion species. The U.S. Patent and Trademark Office awarded Sandia National Laboratories a patent for the design and application of a system that controls the mixing in a pulse combustor. Sandia also demonstrated a technique that allows the utilization of waste organics as fuel with 99.99 percent efficiency.

In 1993, the Combustion Technology Program defined new project areas that will help the pulp and paper and refineries industries deal with toxic emissions and increase their utilization of waste fuels. DOE began an initiative with the Petroleum Environmental Research Forum for R&D on the combustion of refinery process gas to identify the mechanism for the formation of toxic species and the process changes needed to eliminate them. DOE is continuing its cooperative effort with the Gas Research Institute to fund the Burner Engineering Research Laboratory facility at Sandia and conduct testing on advanced natural-gas burners. In addition, the Georgia Institute of Technology is investigating the use of pulse combustion to provide the energy needed for gasification of pulp and paper mill black liquor in fluidized bed reactors.

The use of fossil fuel other than as a feedstock in petroleum and chemical production requires combustion. Approximately 14.8 quads (15.6 exajoules) of the 15.8 quads (16.7 exajoules) used by industry in 1990 for heat and power came from the direct combustion of fossil fuels. Accordingly, the efficiency of industrial fuel combustion has a profound effect on overall industrial energy efficiency and particularly on manufacturing heat and power production. Therefore, any small improvement in combustion efficiency can result in significant U.S. energy savings.

In addition, more stringent regulations require the availability of energy-efficient boilers, furnaces, and other combustion equipment that meet environmental targets in a cost-effective manner. U.S. industry spent approximately \$11.8 billion in 1990 for air pollution abatement from stationary sources, and it spent another \$1.8 billion on R&D related to controlling air emissions. This spending represents a costly drain on economic resources and diminishes the overall competitiveness of U.S. industry. EPACT recognized the need to authorize the development and dem-

onstration of high-efficiency, very-low-emission industrial combustion equipment that meets critical EPA emissions targets without postcombustion emission controls, and that uses natural gas. This equipment will enable U.S. industry to maintain its competitive worldwide position.

Current projects already are making significant strides in improving efficient energy use and reducing greenhouse and pollutant emissions. A key project, undertaken by Praxair (Tarrytown, New York; formerly a unit of the Union Carbide Corporation), has applied nominal 100-percent-oxygen-enriched combustion (oxy-fuel firing) to a Gallo Glass Company (Modesto, California) furnace at the largest container glass plant in the United States. The resulting emissions reductions have been significant: carbon monoxide has been reduced by 96 percent, hydrocarbons have been reduced by 61 percent, particulates have been reduced by 28 percent, and nitrogen oxide has been reduced by 84 percent to one-fifth of the recently adopted California standard for glass furnaces. Fuel consumption and greenhouse gas emissions have been reduced by 25 percent. Encouraged by these results, Gallo has begun converting its remaining furnaces to oxy-fuel firing. Recently, Gallo has replaced liquid oxygen delivered by truck with oxygen that is separated from air by the world's first commercial vacuum-pressure swing absorption system.

Newly identified materials will enable the Alzeta Corporation to construct a porous radiant burner to bring the benefits of this advanced burner to the high temperature and pressures used in the petrochemical industry. An Air Products and Chemicals, Inc., steam reformer that produces hydrogen has been identified as the host site for this project.

A ferrous scrap preheater is in its final design phases at Surface Combustion, Inc. (Maumee, Ohio), before its construction and demonstration in the "minimill" owned by Washington Steel (Pittsburgh, Pennsylvania). By preheating scrap steel, the system will allow the mill to produce more steel in less time and at a lower cost.

Stone and Webster Engineering Corporation (Boston, Massachusetts) and Modar, Inc. (Natick, Massachusetts), are operating a 500-gallon-per-day (1,900-liter-per-day) supercritical water oxidation unit to determine the potential for energy recovery from aqueous industrial wastes. This process, which resulted in 99.999 percent destruction of simulated industrial aqueous wastes, produces no air pollutant emissions, generates water that meets EPA groundwater standards, and produces solids that meet EPA landfill requirements. Surface Combustion and Textron Defense Systems are developing a workpiece analyzer, a noncontact laser-based system that can measure the temperature of metals undergoing heat treatment. The appli-

cation of advanced signal-processing techniques from the defense industry has made such high-temperature, remote temperature measurement practical for the first time.

Engine Combustion Technology

During 1992 and 1993, four engine combustion working groups continued to investigate the technical issues critical to improving the efficiency of combustion in engines to reduce fuel consumption or emissions. These working groups, composed of engine manufacturers (General Motors Corporation, Chrysler Corporation, Ford Motor Company, Cummins Engine Company, Caterpillar, Inc., Detroit Diesel Corporation, and others), petroleum companies (Exxon, Unocal, Texaco Inc., and Mobil), national laboratories (Sandia, Lawrence Livermore, and LANL), and major universities, worked cooperatively to investigate and advance understanding of internal-combustion processes. Engine combustion working groups were directed toward innovative engine concepts and combustion processes, such as direct-injection stratified-charge engines, two-stroke engines, dilute homogeneous-charge engines, advanced diesels, natural-gas diesels, and fuel tailoring and emissions interactions.

Sandia National Laboratories transferred its ionization-probe-instrumented head gasket and its fiber-optic spark plug technology to Southwest Research Institute for commercial manufacture. Engine manufacturers are using these two diagnostic tools to identify autoignition causes and solutions. *Research and Development* magazine presented Sandia with the R&D 100 award (presented for the top 100 technological achievements of the year, typically innovations that transform basic research into useful products) in 1992 for the development of the head gasket. Researchers at Lawrence Livermore National Laboratory and General Motors Corporation received the Horning Memorial Award of the Society of Automotive Engineers for the best work of 1992 relating fuels and engines to the effectiveness of antiknock compounds. Cummins Engine Company has used the KIVA-III model (a comprehensive modeling tool developed by the Combustion Program) to redesign the cylinder head of its "heavy-duty" diesel engine to increase the efficiency 10 percent.

Process Heating and Cooling

Industry annually consumes 17 quads (18 exajoules) of energy for heating and cooling, using a variety of energy conversion equipment and systems that operate in a wide

range of temperatures and environments. Estimates show that more efficient use of process heat could have significant energy benefits. For example, using heat pumps to recover waste heat could potentially save more than 1.5 quads (1.6 exajoules) per year. To realize these benefits, OIT conducts R&D on a variety of process heat and cooling equipment and systems used by a number of different industries. Program research has focused on heat pumps and heat exchangers, as well as the fundamental thermophysical processes that underpin energy conversion technologies.

Current projects being conducted under the Process Heating and Cooling Program could reduce U.S. energy use by 1.3 quads (1.4 exajoules). Environmental benefits from technology under development in the program could be significant: reduction of sulfur oxides by 390,000 tons (350,000 metric tons) per year, reduction of NO_x by 290,000 tons (260,000 metric tons) per year, and reduction of carbon dioxide by 100 million tons (91 million metric tons) per year. Increased sales of equipment from use of these new technologies is projected at \$600 million per year.

Advanced Heat Exchangers

The Process Heating and Cooling Program is developing ceramic high-pressure heat exchange systems (HiPHES) that will operate at elevated temperatures and at significant pressure. DOE projects energy savings of 0.63 quad (0.66 exajoule) annually from HiPHES technology. As a methane reformer, the HiPHES unit would reduce feedstock and energy requirements by 30 percent. Similar HiPHES equipment could recover heat from industrial hazardous waste incinerators to generate electricity while continuing to safely dispose of the noxious materials. Using HiPHES to reduce hazardous-waste-stream temperatures would obviate the need to quench the waste stream and would eliminate the resulting liquid waste disposal problem. In 1993, design efforts continued, and testing of materials under both reformer and hazardous waste incinerator environments was initiated.

Industrial Heat Pumps

Process-integrated and chemical heat pumps could save 0.60 quad (0.63 exajoule) per year by displacing fuel burned for boiler steam or process heat. OIT heat pump research is using pinch analysis, a process heat integration tool, to identify optimal locations for heat exchange options (for example, heat pumps in industrial processes). Seventeen case studies by industrial firms and their utili-

ties using this technique have resulted in excellent heat pump opportunities, and eight have been selected for detailed heat pump installation designs. In 1991, one heat pump installation was completed; others are scheduled for design and installation. Work continued at 3M and Nucon International on the Brayton-cycle solvent recovery heat pumps to recover and recycle volatile organic compounds back to reusable solvents (alternative methods involve incinerating the compounds with supplemental fossil fuel). Three commercial Brayton-cycle solvent recovery systems—designed, built, and installed by Nucon—are operating to date and are capturing more than 1,500 tons (1,400 metric tons) of volatile organic compounds per year.

In 1993, Nucon demonstrated a mobile Brayton-cycle system at multiple sites in Los Angeles, California. In addition, in 1993, DOE supported two firms in the design and fabrication of a full-scale liquid-vapor chemical heat pump (Litwin Engineers and Constructors of Houston, Texas, and Energy Concepts Company of Annapolis, Maryland) and a solid-vapor chemical heat pump (Rocky Research of Boulder City, Nevada, and Standard Refrigeration of Chicago, Illinois). These firms are building the chemical heat pumps for industrial host sites.

Electric Motor Systems

Electric motor applications use more than half of all electricity in the United States. The cost of powering motor systems is immense—roughly \$90 billion a year in the United States. In the past it has been difficult to identify differences in energy performance between standard (defined by the National Electrical Manufacturers Association) and more efficient motors. Now, with the development of the MotorMaster computer program, information on thousands of three-phase motors has been collected in a computerized data base. With support from OIT, the Washington State Energy Office has distributed the MotorMaster software package nationally to more than 2,000 utilities and to every state energy office. Many Federal facilities have received copies of the data base as well. Building on the success of the MotorMaster program, OIT initiated the Electric Motor Systems Program to promote a better understanding of electric motor systems and the use of such systems more efficiently.

The Program sponsored a conference on energy-efficient electric motor systems (cost-shared with the Electric Power Research Institute), which attracted more than 400 participants representing all aspects of electric motor systems. The program also held a roundtable on efficient industrial electric motor systems, with 40 industry experts, which addressed market barriers associated with efficient

electric motor and drive systems and possibilities for reducing or removing those barriers. The program distributed a sourcebook containing technical and market information on electric motor systems and a report on the results of the Expert Roundtable, and completed a survey of 500 motor systems at the Federal Naval Petroleum Reserves.

Thermal Sciences

To help industries improve their heat exchangers and process equipment, the OIT Thermal Sciences Program sponsored research during the reporting period to better understand the conversion and transfer processes of heat and fluid flows that take place in the equipment's operations. Researchers focused on prediction methods for developing enhanced heat exchangers, fouling prediction and mitigation for heat exchangers and process equipment, phase-change heat transfer characterization for developing high-performance compact heat exchangers, ammonia-water mixtures as alternative refrigerants to chlorofluorocarbons (CFCs), and computational methods for simulating and possibly designing non-CFC working fluids.

Industry can save enormous amounts of energy if enhanced surfaces come into wide use in heat exchangers. The major barrier to this application is the lack of reliable data and prediction methods. Researchers at Argonne National Laboratory and several universities conducted numerical modeling and heat transfer experiments to develop an integrated technology base that will enable industrial designers to select an optimal enhanced surface for a specific application, with fouling propensity included in the considerations. Fouling of equipment significantly reduces the efficiency of process operations and cumulatively increases capital and operating costs. Despite fouling's large cost to industry, which is estimated at several billion dollars annually, fouling reduction R&D to assist designers and operators of heat exchangers and process equipment has been minimal. Following up on the fouling research, Argonne National Laboratory, the Chevron Research and Technology Company (Richmond, California), and Heat Transfer Research, Inc. (College Station, Texas), established a CRADA to mitigate fouling in hydrotreating units in processing of residual and heavy oils. DOE will direct more efforts toward helping industries treat the fouling problems encountered in process operations. Compact heat exchangers (such as evaporators and condensers) are traditionally used in automobile air conditioners. These devices are small and lightweight and provide high thermal performance and design flex-

ibility, and there is widespread interest in expanding their applications to process industries. As designs for yet more compact heat exchangers require yet smaller flow passages, industry urgently needs knowledge of how the fluids behave in such small passages so that it can establish a reliable design technology. Researchers continued to make progress in characterizing flow boiling and condensing in small passages (for example, rectangular passages of 4 by 2 millimeters).

Argonne National Laboratory and the Modine Manufacturing Company (Racine, Wisconsin) established a CRADA to develop high-performance compact heat exchangers. Although ammonia-water mixtures have long been used as working fluids in absorption refrigeration technology, very few design data are available. The Montreal Protocol requires the phaseout of CFCs by the year 2000, and ammonia-water mixtures are being promoted as alternatives. ORNL has established a CRADA with Exergy, Inc. (San Francisco, California), the developer of Kalina power systems (advanced, binary working-fluid energy conversion systems), to perform ammonia-water condensing experiments. Information obtained from the experiments will be used for equipment design in Kalina power systems and absorption refrigeration units. Recently, Exergy has entered a worldwide licensing agreement with General Electric Company to further develop and market Kalina power systems. In DOE's search for environmentally benign working media, Pacific Northwest Laboratory is developing a general-purpose code for simulating working fluids. Researchers have already used the code to simulate the CFC refrigerants R-12 and R-134a. The ultimate goal of this research is to develop a tool to design environmentally safe working fluids.

Cogeneration

Cogeneration is the simultaneous production of electricity (or mechanical energy) and useful heat (thermal energy) from the same fuel source. Generating electricity on the "once-through" basis of fuel use for electricity production has an efficiency of 30 to 40 percent; by using or converting the waste heat to steam for process or district heating, cogeneration can increase overall fuel efficiency to 80 percent. Industrial cogeneration capacity potentially can be expanded to supply more than 75,000 megawatts by the year 2000 (from 32,000 megawatts today), with resulting annual savings of almost 2.0 quads (2.1 exajoules) of primary energy.

Such an expansion would eliminate the need for approximately 15 new powerplants to meet future industry demand. However, many industries are unable to take advantage of the cogeneration concept because their processes require higher electrical-to-thermal output ratios than standard steam turbine systems provide. The objective of the Cogeneration Program is to develop equipment with high electrical output (relative to thermal output) for advanced cogeneration systems, which will increase their applicability in industrial settings.

Research in advanced cogeneration systems in 1992 and 1993 concentrated on the development of high-performance steam turbines, ceramic retrofit components for existing turbines, advanced turbine systems, and supporting research.

The high-performance steam turbine project is developing a turbine that can operate at steam conditions of 1,500 pounds per square inch (10 megapascals) and 1,500 degrees Fahrenheit (820°C), representing a 300 to 400°F (170 to 220°C) increase in normal operating temperatures; to improve efficiency by 5 percent. A 4-megawatt steam turbine and a full-scale heat recovery steam generator are under construction; factory testing will occur in 1994, and a 1,000-hour field test is scheduled for 1995. Innovative Steam Technologies (San Diego, California) is the prime contractor, with support from Coen Burner Company (California), Fisher Value Company (Atlanta, Georgia), INCO (Huntington, West Virginia), and Precision Cast Parts (Portland, Oregon).

The ceramic retrofit components project will place high-temperature ceramic replacement parts into key components of a commercial industrial stationary gas turbine to achieve a 9-percent increase in efficiency and a 25-percent increase in power output. The prime contractor is Solar Turbines, Inc. (San Diego), with 12 subcontractors, including the AlliedSignal Aerospace Company (Torrance, California); the Norton Company (Northboro, Massachusetts); the Babcock and Wilcox Company (Lynchburg, Virginia); DuPont Chemical (E. I. DuPont de Nemours & Company, Wilmington, Delaware); the Carborundum Company (Buffalo, New York); the Atlantic Richfield Company (Alexandria, Virginia); and the Sunstrand Corporation (San Diego, California). The ceramic replacement parts include the combustor, the first-stage nozzle, and the first-stage blade and transition pieces. The project will culminate in a 4,000-hour field demonstration at an oil and gas facility.

The 8-year advanced turbine systems program is jointly run by the Assistant Secretary for Energy Efficiency and Renewable Energy and the Assistant Secretary for Fossil Energy. The goal is 15-percent-improved thermal effi-

ciency, single-digit nitrogen oxide emissions, and lower cost electricity. DOE made concept awards to two gas turbine manufacturers in July 1993 for the development of industrial-scale turbines: one to Solar Turbines, Inc. of San Diego and one to Allison Turbines, Inc., of Indianapolis. In addition, the Office of Fossil Energy made two awards to continue the development of utility-scale engines.

In support of cogeneration development, ORNL is testing ceramics for up to 10,000 hours to establish long-term materials performance.

A project cost-shared by the Santa Barbara County Air Pollution Control District, the Gas Research Institute, Southern California Gas (Santa Barbara), and the Chevron Corporation (Richmond, California) is funding the Allison Gas Turbine Engine Company (Indianapolis, Indiana) to modify combustors to reduce nitrogen oxide emissions.

BUILDING TECHNOLOGIES

Introduction

The building sector used approximately 29 quads (31 exajoules) of primary energy in 1991 (Figure 1-12). Although there have been dramatic improvements in energy efficiency in this sector in recent years, the rate of improvement seems to be slowing, while energy consumption is growing rapidly—annual building energy use increased 4.2 quads (4.4 exajoules) from 1981 to 1991. If this trend continues, total consumption in the building sector could increase to some 55 quads (58 exajoules) by the year 2030.

The U.S. building industry is fragmented, conservative, and subject to the demands of a highly variable market. Therefore, most segments of the industry invest little in R&D. In addition, diffusion of new technologies has been very slow, and many parts of the industry, especially equipment manufacturers, are subject to increasing foreign competition.

To support private-sector efforts to increase the energy efficiency of the Nation's residential, commercial, and industrial buildings, as well as to enhance their use of renewable energy supplies, the Office of Building Technologies (OBT) manages a national program of technology planning, R&D, technology transfer, and testing and evaluation. OBT also provides support for managing Federal energy programs and manages regulatory programs that

1-12. End-use analysis of building energy consumption helps identify opportunities for efficiency improvement.

promote the efficient use of energy in buildings. The office develops, executes, and evaluates programs to provide timely transfer of program-specific technologies from Federal laboratories and contractors to the private sector and to facilitate informed decision-making by energy users.

Scope of Program

OBT's research program is designed to assist the private sector in creating a new generation of buildings that will use energy efficiently and cost-effectively. In cooperation with industry, OBT is developing energy-efficient and renewable energy technologies that substantially reduce the consumption and cost of nonrenewable energy in buildings. As a part of this research, OBT is establishing the technology base for improving materials and structures,

lighting and appliances, heating and cooling equipment, and advanced design and manufacturing processes. OBT collaborates with industry, utilities, states, and other Federal agencies to validate the performance of newly emerging technologies. OBT also manages the Federal Energy Management Program to improve the energy efficiency of Federal buildings, facilities, and operations. OBT collaborates with other government agencies and the private sector to conduct research on critical energy-related issues, such as the use of CFC substitutes as refrigerants and foaming agents for insulation. To facilitate the deployment and acceptance of technologies, OBT identifies barriers to the market and helps to eliminate them through information, financial, and congressionally mandated regulatory programs.

In developing policies and priorities for building technologies and energy efficiency planning and management, OBT considers and evaluates national economic and energy policies and programs, current and prospective do-

mestic and international energy demands and use, and the availability of Federal funding. OBT defines specific program activities that reflect the scientific and technical potential of renewable energy and energy-efficient building technologies; industrial, economic, environmental, and financial concerns; and the capabilities, knowledge, decision practices, and interests of energy users.

Materials and Structures

To improve the energy efficiency of new and existing buildings, the energy losses through the building envelope (the materials and structures that form the building's exterior) must be substantially reduced. The program goal is to provide the technology for building design options for the year 2000 that require zero net heating and minimal cooling energy. To reach this goal, materials and structures research focuses on building materials; walls, roofs, and foundations; and windows and glazings. This research includes the development of new building envelope technologies with high thermal resistance, improved use of solar energy, and the development and dissemination of new design and performance knowledge for the best use of existing and new technologies.

Building Materials Research

The energy performance of a building largely depends on the thermal properties of the materials from which it is built. By impeding the flow of heat, thermal insulation protects the conditioned interior space of a building from the exterior environment. Appliances (such as refrigerators and water heaters) also use thermal insulation to improve their energy efficiency.

OBT's emphasis in building materials research has been on developing, testing, and demonstrating cost-effective materials to substantially improve the energy efficiency of buildings and appliances and to eliminate the need for ozone-depleting CFCs, which are commonly used as blowing agents in foam insulation. DOE is supporting the development of superinsulation concepts, including the gas-filled reflective panel, compact vacuum insulation, and the powder-filled evacuated panel, which 1-inch (25-millimeter) thick and has a thermal resistance (R-value) in excess of 20 square-foot hour degrees Fahrenheit per British thermal unit (3.5 square-meter kelvins per watt).

DOE's assessments of residential and commercial building technologies predict that superinsulation and building envelope materials with controllable thermal properties

could reduce the building sector's annual heating and cooling energy use by 30 percent, utilities' peakloads by 20 percent, and refrigerator and freezer energy consumption by 40 percent. The potential savings from full use of these new materials is 8 to 10 quads (8 to 11 exajoules). Tripling the R-value of refrigerator insulation alone would save about 1 quad (1 exajoule) annually.

DOE completed a joint project with industry and EPA on the elimination of CFC blowing agents. The Appliance Research Consortium, a subsidiary of the Association of Home Appliance Manufacturers, did the work under a cooperative research and development agreement (CRADA). The consortium has approved a new project to compare the thermal and physical characteristics of polyurethane foams blown with hydrochlorofluorocarbons (HCFCs), which have lower ozone-depleting potential than CFCs.

PPG Industries and ORNL have signed a CRADA for joint R&D on powders for one of the most promising superinsulation approaches, the powder-filled evacuated panel, which consists of a slab of powder encased in a plastic film with a soft vacuum in the interior. The key element in the concept is the powder, which determines the thermal performance (R-value) and is the most significant cost factor of the finished panel. Research under the CRADA will develop a correlation between powder morphology and thermal properties.

The process of developing better insulating materials requires the development of advanced methods to test their thermal performance. In addition, because many insulations (including foam and vacuum types) show decreased performance over the 20- to 100-year lifetime of most building applications, insulation manufacturers need accelerated methods to predict this performance within a convenient timeframe. In 1992, DOE developed a lifetime test procedure for powder-filled evacuated panel insulation.

Walls, Roofs, and Foundations

As the thermal barrier between the conditioned indoor space and the outdoor environment, the envelope of a building—its walls, roof, and foundation—is a key determinant of its energy requirements. OBT's research in building envelope systems emphasizes the development of new wall, roof, and foundation systems that substantially increase the energy efficiency of buildings and that are environmentally benign. In addition, the research focuses on critical issues related to the entire building envelope, such as moisture control.

The Building Envelope Research Center at ORNL, a DOE-designated user facility, supports in-house research by ORNL staff as well as cooperative research with industry through CRADAs. Researchers are using instrumented laboratory chambers and specially designed outdoor structures for environmental tests of low-slope roof and attic systems to further characterize thermal performance.

ORNL's research with the 4,000-cubic-foot (100-cubic-meter) Large Scale Climate Simulator, with its mock attic for testing insulation, won a 100 Best of What's New Award, presented by the editors of *Popular Science* magazine for achievements in science and technology and reported in the December 1992 issue. The research found that natural convective circulation significantly reduces the thermal resistance of some low-density, loose-fill insulation as the air temperature decreases. When the attic temperature is below 10°F (−12°C), the insulation R-value is as much as 50 percent less than its nominal rating. The same research confirmed the efficacy of polyethylene film for stopping the convective heat loss through the insulation. These findings are having significant effects on the insulation industry. The State of Minnesota has revised its building code to require that all insulation materials achieve their stated R-values at design temperature instead of at 75°F (24°C). A Minnesota court upheld this revision, which would effectively derate the R-values of loose-fill fiberglass insulation. The findings are likely to result in new national standards that could cause manufacturers to reduce their stated R-values to reflect insulation performance in actual winter conditions. To provide builders and architects with the essentials of attic design for high thermal efficiency, ORNL is summarizing the results of insulation performance tests in attic systems in an attic design handbook.

The Large Scale Climate Simulator can create conditions to simulate the weather in any part of the world. In the summer of 1992, it set a record low temperature, −30°F (−34°C) for 72 hours, when peak ambient temperature was 88°F (31°C). For comparison, Bemidji, Minnesota, has a design winter temperature of only −26°F (−32°C), the lowest such temperature in the state.

ORNL and three industry associations have extended their CRADA supporting the development of CFC-free, high-R-value foam insulation boards for a second 3-year (1993 to 1995) phase at an increased level of cost sharing, with \$2 of industry funds matching each \$1 of DOE funds. Industry participants are the Polyisocyanurate Insulation Manufacturers Association, the Society of the Plastics Industry, and the National Roofing Contractors Association. Polyisocyanurate rigid foam board is used in approximately 50 percent of all new commercial roofing

insulation applications and in 40 percent of all residential sheathing applications. The CRADA has helped private industry develop CFC-free polyisocyanurate insulation products that are currently on the market. Under the 3-year extension, data collection will continue on foam boards blown with trichlorofluoromethane (CFC-11) and with HCFC-141b, the leading non-CFC alternative, in both the Roof Thermal Research Apparatus and the Envelope Systems Research Apparatus. In addition, ORNL has begun the development of low-permeability facers for the insulation boards.

Windows and Glazings

Unwanted heat losses and solar heat gains through windows in buildings in the United States cost some \$20 billion per year, representing approximately 5 percent of the total U.S. primary energy consumption, or about one-fourth of all the energy used for heating and cooling of buildings. A 1993 study by LBL showed that energy loss through residential windows in the United States amounts to 2.4 quads (2.5 exajoules) annually. However, LBL calculated that the use of emerging technologies could reduce this figure to well under 1 quad (1 exajoule) annually. The study also showed that the Nation is saving 0.4 quad (0.4 exajoule) annually from improvements in residential window technologies developed over the past decade. Commercial buildings experience similar, although somewhat more complex, energy impacts from windows.

The OBT program in window and glazing research addresses the development and characterization of advanced window and glazing technologies to reduce heating, cooling, and lighting loads in buildings. This research provides industry with a technology base and support for product and process development. Research is also establishing the technical basis to determine window performance through simulation, testing, and evaluation. The application of this performance research includes the development of a window rating and labeling program, support for utility demand-side management programs, and the development of design tools and handbooks. Further, OBT provides technical and analytic support to industry for investment analyses and business planning. The goal of all these activities is to accelerate market penetration of advanced window technologies (Figure 1-13).

One of the major accomplishments of the window and glazing program has been the development of highly insulating "superwindows" to reduce the heating requirements of a building in a cold climate. Superwindows combine low-emissivity coatings, low-conductance gas fills, and new insulating window frames and edge spac-

I-13. DOE windows research aims to accelerate the market penetration of advanced window technologies.

ers. They have such low thermal losses that even the small amount of diffuse sunlight from the north sky provides heat that exceeds the losses, converting the window into a net supplier of energy in winter. An LBL paper in December 1992 presented results from thermal imaging studies and two-dimensional finite-difference modeling to improve the thermal performance of commercially available vinyl window frames. Vinyl frames have gained an increasing share of the residential window market due to their low manufacturing cost, and they are candidates for use in superwindows. In recognition of their efforts in the development of the technology base for superwindows and its transfer to the U.S. building industry, two LBL researchers, Dariush Arasteh and Stephen Selkowitz, received a Federal Laboratory Consortium Award for Excellence in Technology Transfer.

Improvements in coating technology allow durable low-emissivity coating of single-pane glass. Field studies with the Mobile Window Thermal Test Facility (MoWiTT) have shown that low-emissivity storm windows on conventional single-glazed windows reduce energy loss by an average of 71 percent relative to single-glazed windows alone and 16 percent relative to conventional storm windows with single-glazed windows. The studies, which have been sponsored by a major glass manufacturer, are stimulating new interest in storm windows, along with the availability of

utility demand-side management rebates for glazing retrofits.

LBL opened its Infrared Thermography Laboratory to industry for testing thermally improved glazings and frames, and cooperative research projects are under way. The laboratory's equipment allows precise temperature measurements across the window and frame surfaces, giving manufacturers information to improve the designs of their products.

Filling the space between panes in double-glazed windows with a low-conductivity gas improves the windows' thermal performance, but conventional filling techniques waste gas and often result in poor fills. In 1992, LBL patented an innovative vacuum chamber technique that it had developed, and several manufacturers are considering using it in their production process. The method allows the filling of insulating windows to a very high percentage with almost no loss of gas. With high-performing but expensive gases, such as krypton, this procedure can be significantly more cost-effective and efficient than conventional gas-filling procedures.

Spectrally selective coatings can fine-tune the characteristics of glazing by admitting daylight with minimal solar gain. Windows with spectrally selective glazings can reduce electricity use and peak demand in homes in the Sun Belt and in commercial buildings nationwide. A March

1992 workshop, organized by LBL and cosponsored with manufacturers and utilities, brought together more than 100 participants from industry, utilities, state energy offices, architectural firms, and research groups to promote wider application of this technology.

Performance and simulation research supports the development of design tools to expand the adoption of advanced window technologies. These tools enable engineers, architects, designers, and utility demand-side managers to determine the energy performance of new window technologies. After extensive review by industry, LBL released the computer program WINDOW, version 4.0, for evaluating the thermal performance of windows. The National Fenestration Rating Council (NFRC) adopted the program for use in simulating window thermal performance as a part of NFRC-100.91, "Procedure for Determining Fenestration Product Thermal Properties (Currently Limited to U-Value)." Additional software developed by LBL included test versions of SUPERLITE 3.0, which models daylight from complex glazings, and RESFEN, which determines fenestration loads in residential units.

A window with switchable optical properties could optimize the use of daylighting, thus reducing the need for electric lighting while also reducing cooling loads from solar heat. DOE research has focused on the electrochromic window, in which a small electric current changes and controls heat and light transmittance. Targeted benefits include a 70-percent reduction in perimeter zone electric lighting loads and a 20-percent reduction in peak cooling loads. In collaboration with industry, LBL has defined the performance and cost requirements for electrochromic windows and completed a cost-shared assessment on spectrally selective and electrochromic window performance in office buildings in hot California climates. The Department continued its progress on electrochromic device development with leading glass and window manufacturers, including LOF Glass, Dow Chemical Company, and Southwall Corporation.

A collaboration between the LBL Windows and Daylighting Group and the electrochemistry program at LBL has developed an electrochromic device that uses a hybrid laminated polymeric ion conductor (patent pending) and solid-state layered construction. The laminated layer, which can be combined with many alternative electrochromic materials, promises a significant simplification in device design and fabrication. The new device with this conductor can modulate light transmission between 10 and 60 percent while reducing transmitted sunlight by more than 90 percent in its darkened state. An LBL announcement describing the new technology and

the licensing opportunities has generated a number of inquiries from the private sector.

Section 121 of EPACT requires the Secretary of Energy to support a voluntary national window rating program, to be developed by NFRC, and to determine, within 1 year after EPACT's enactment (by October 24, 1993), whether the program developed by NFRC is consistent with the objectives of the act. If not, the law requires DOE to develop its own program.

A consortium of industry, utilities, government, and public interest groups, NFRC was organized in 1989 to establish a rating system for the energy performance of windows and to coordinate certification and labeling activities to ensure their uniform application (Figure 1-14). NFRC's rating system will be used by product manufacturers in marketing products, by governmental agencies in establishing fenestration standards, and by utilities in offering financial incentives for the installation of higher performance windows. A significant accomplishment in 1992 was the development, testing, and validation of the first uniform national procedure for rating the thermal transmittance of fenestration products, NFRC-100.91. Accompanying this process was the development of a system for evaluating and accrediting the technical competence of simulation and thermal testing laboratories to offer the rating services. NFRC initiated procedures for rating additional window parameters, including solar optical properties, solar heat gain, and air infiltration, and they are now approaching completion and final adoption. NFRC also developed and implemented a certification and labeling system for the thermal performance rating of fenestration products in California, which went into effect on January 1, 1993. A number of other states have adopted NFRC ratings. OBT cosponsored NFRC activities, and much of the technical basis for NFRC test procedures came from OBT-sponsored research.

Lighting and Appliances

Residential appliances, including heating and cooling equipment and water heaters, consume more than 19 quads (20 exajoules) of source energy, or 70 percent of all the energy used in the residential sector. In addition, lighting in the commercial sector consumes an additional 4 quads (4 exajoules) of source energy. The goal of the Lighting and Appliance Program is to annually save more than 4 quads (4 exajoules) of primary energy by the year 2010, with accompanying improvements in environmental quality.

National Fenestration Rating Council			
AAA Window Company					
Manufacturer stipulates that these ratings were determined in accordance with NFRC 100-91. SM					
U-value	AA	5' x 3'	0.40	Model #1500 Horizontal Slider 0.5" Air Space, Low-e 0.2	
U-value	BB	6' x 4'	0.38		

1-14. A nationally recognized energy performance rating system for windows and skylights has been initiated.

Advanced Lighting

Lighting in buildings consumes some 6 quads (6 exajoules) of source energy, or nearly 20 percent of the total U.S. electricity purchased, at a cost of almost \$40 billion annually. Lighting is a major contributor to electric peakload in commercial buildings, not only directly but also indirectly, through increased air-conditioning required to remove the heat produced by lighting. The technological potential exists for a 50-percent reduction in this energy consumption through completely new light source technology. To accomplish this, LBL has conducted research on three related lighting activities: development of advanced light sources; application of new technology and design methods to building lighting systems (Figure 1-15); and investigation of the impacts of lighting on vision, health, and workplace efficiency.

DOE's lighting program concentrates on the rapid development, through cooperative projects with lighting and electronic companies, of very-high-frequency (VHF) electrodeless lamps and fixtures. The VHF electrodeless lamp concept could lead to a 40-percent increase in fluorescent lamp efficiency, a truly compact fluorescent lamp with greater than 75-watt equivalent output, and a high-intensity-discharge lamp with high efficiency in small sizes. In 1992, LBL demonstrated that the VHF fluorescent lamp's output is sufficient to replace existing, conventional

1-15. Lawrence Berkeley Laboratory researchers are developing improved lighting fixtures that improve light output by controlling lamp temperature.

fluorescents. LBL is adapting the lamp's basic design to include a compact fluorescent VHF type to replace incandescents of 75 to 150 watts, a market gap not filled by current compact fluorescents, as well as 4-foot (1.2-meter) tubular and biaxial versions. The VHF-high-intensity-discharge lamp's output is sufficient to replace incandescent lamps of 25 to 250 watts. LBL is developing the power supply, a crucial component of the lamp system, in cooperation with the electronics industry.

DOE and LBL signed a codevelopment contract with Fusion Systems, Inc., to make a new mercury-free VHF light source, the "S-lamp," to replace compact fluorescent and incandescent lamps. The S-lamp is highly efficient, has excellent color quality that closely matches the visual response of the human eye, lasts an estimated 40,000 hours, and is environmentally safe (because it uses no mercury). The firm is using just one of these lamps, a spherical bulb 1 inch (2.5 centimeters) in diameter and

driven at 3,500 watts, to light a large portion of its factory. Simply constructed light pipes optically distribute light from this central source throughout the factory area. At present the firm has only been able to operate the lamp at kilowatt power levels suitable for outdoor, industrial, or stadium lighting. Technical collaboration with LBL will focus on making a low-power lamp for building applications, using the company's proprietary techniques and LBL's expertise in electronic excitation. An additional application is the integration of the high-power light source into core daylighting systems in buildings, where it can serve as an artificial sun, with its light output distributed through the same optical system as natural sunlight. A demonstration of the high-power light source is planned for the Smithsonian Air and Space Museum, the first public building in the United States to use this new type of lamp.

LBL's initial research has shown that if optimum-spectrum lamps have no adverse effects on human workplace performance, they could provide up to 20-percent energy savings. DOE is working with industry to validate the use of optimum-spectrum lamps in realistic workplace settings to estimate their energy savings and to facilitate their market acceptance. A major lamp manufacturer has produced lamps that use a modified triphosphor for laboratory testing. An astronaut crew recently chose scotopic, optimum-spectrum lighting over other types of lighting in a series of tests run by human-factors scientists at the National Aeronautics and Space Administration. The astronauts made their choice on a subjective basis, for the visual comfort and improved visibility that optimum-spectrum lighting provides.

The goal of DOE's collaboration with the lighting fixture industry is to improve the energy efficiency of fixtures by at least 25 percent. In 1992 and 1993, manufacturers introduced several new products into the commercial market incorporating DOE-developed thermal control strategies. The U.S. Patent and Trademark Office awarded two patents to the Department for thermal control devices for lamps and fixtures. The Illuminating Engineering Society of North America presented its 1992 Product of the Year Awards for fixtures from three manufacturers using the technology, which achieves significant energy savings with little additional cost.

Industry is evaluating RADIANCE, an LBL computer program that provides accurate computer-generated pictures of building interior spaces to aid the design of energy-efficient lighting environments. To increase the program's potential for widespread use, LBL will link RADIANCE to existing computer-aided building design software and transferred to the private sector. LBL staff also assisted the Architect of the Capitol with a planned

energy-efficient retrofit of lighting in the Capitol office complex.

Noting the increased regulatory attention to the disposal of fluorescent lamps, the National Electrical Manufacturers Association asked LBL to investigate the environmental release of mercury from fluorescent lamp manufacturing and lamp disposal. A draft report (April 1993) showed that these releases are much smaller than those entering the biosphere from the combustion of fossil fuels to generate the electricity required for incandescent lamps with equivalent light output. In addition, the form of mercury released in powerplant exhaust is substantially more hazardous, because it is chemically more conductive for uptake by biological systems. LBL plans a second study to investigate the mechanisms and extent of landfill mercury entry into the biosphere.

LBL staff helped the California Energy Commission and the Electric Power Research Institute prepare an updated version of the commission's popular *Advanced Lighting Guidelines* series, which summarizes the most recent information on energy-efficient lighting technology. The commission distributed more than 10,000 copies of the first edition of these reference booklets; in addition, EPA distributed 2,000 copies to its partners in the Green Lights Program, a voluntary program to encourage companies to use commercially available energy-efficient lighting technologies. Four booklets have been added to the original eight booklets in the series, with each treating a different area of efficient lighting technology. The new booklets are devoted to time-based control systems, occupant sensors, daylighting integration, and control retrofit technologies. DOE published the updated edition in 1993.

LBL completed a major report, *Analysis of Federal Lighting Policy Options for Improving U.S. Lighting Energy Efficiency: Commercial and Residential Buildings*, which analyzes selected policy options for reducing electricity use, peak demand, emissions, and associated costs of improving the end-use energy efficiency of lighting. The report concludes that, although the various Federal policy alternatives are qualitatively different, the maximum potential savings in energy costs is in the range of \$100 billion, in terms of net present value.

Heating and Cooling Equipment

Heating and cooling equipment consumes 13 quads (14 exajoules) of primary energy, 46 percent of all the energy consumed in residential and commercial buildings in the United States. Together with associated refrigera-

tion equipment, heating and cooling equipment is a major user of CFCs. The technological potential exists for saving 50 percent of this energy and eliminating the use of CFCs completely. Air-conditioning is the single leading cause of electric system peakloads, which can be greatly reduced through advanced technology. These savings translate to substantial reductions in associated emissions and will help secure domestic energy supplies—two primary goals of the National Energy Strategy.

The objectives of the Heating and Cooling Equipment Program are to reduce building energy use by 50 percent or more in order to reduce electric peakloads in buildings by 25 to 50 percent, eliminate the use of CFCs, and significantly reduce carbon dioxide, as compared with the best available conventional equipment technology. The program includes work on space-conditioning equipment, refrigeration systems, and thermal distribution and controls.

Space-Conditioning Equipment

The goals of the Heating and Cooling Equipment Program's space-conditioning equipment activity are to develop the technology to use fossil fuels with a heating coefficient of performance (a measure of energy efficiency) of 2.0, compared with a maximum of 0.95 for the best conventional equipment currently available; eliminate the use of CFCs in heating and air-conditioning equipment; and greatly reduce the impact of air-conditioning on electric peakloads.

Thermally Activated Heat Pumps

The Heating and Cooling Equipment Program has been investigating three types of thermally activated heat pumps: absorption systems, Stirling-engine-driven systems, and internal-combustion engine systems. Through the more efficient use of natural gas, these heat pump concepts could double the efficiency of natural-gas heating and reduce the impact of electric peakloads caused by cooling (Figure 1-16). Absorption technology also eliminates the need for CFCs and reduces the amount of carbon dioxide emitted into the atmosphere. All three heat pumps have particular potential advantages, and all require significant development, but absorption technology appears to be nearest to widespread commercialization. The Heating and Cooling Equipment Program focuses on industry cooperative projects that can rapidly complete the development of the absorption technology and that have the highest potential major performance advances and commercial development in the near term. DOE provided partial funding for the writing of a textbook, *Heat Conversion Systems* (July 1993), presenting the advances in these and similar technologies.

1-16. Thermally activated heat pumps use abundant natural gas for high-efficiency heating and cooling without using ozone-depleting refrigerants.

ORNL is developing the generator-absorber heat exchange cycle for use as a first-generation residential absorption heat pump. Critical components are under development, and they have achieved 80 percent of the target cooling efficiency at reduced capacity. Carrier Corporation, the world's largest manufacturer of heating, ventilating, and air-conditioning (HVAC) equipment, completed the second of three steps of a licensing agreement with the developer, Phillips Engineering, for worldwide rights to the generator-absorber heat exchange technology. Licensing was completed in 1993.

Cost-shared R&D of an advanced-cycle commercial chiller (cooling capacity of more than 100 tons, or 350 kilowatts) is aimed at a potential coefficient of performance of 1.6. The system uses a standard lithium bromide solution but is operated at a higher temperature than conventional chillers. ORNL selected materials and additives to inhibit corrosion, a major area of concern, and began fabrication and testing on a laboratory breadboard unit. In collaboration with a major U.S. equipment manufacturer, York, it is now building a full-scale unit.

DOE research is characterizing new absorption fluids that can achieve 25-percent higher efficiencies than conventional fluids in a first-generation system. Following a screening of multicomponent fluids for advanced-cycle systems, ORNL selected ammonia-water mixtures and evaluated them for corrosion and stability. ORNL is developing a computer model for simulation and analysis of complex cycles, and characterization of transport and thermophysical properties has begun.

ORNL is developing two free-piston Stirling engine compressor design concepts for use as prime movers for residential heat pumps. At a contractor design review in August 1992, Arthur D. Little, Inc., evaluated the designs and discussed the issues critical to the implementation of the technology. Manufacturers need adequate data on bearings and seals to assess the commercial viability of the system. Research at Mechanical Technology, Inc., is already addressing another major issue, emissions. Mechanical Technology and Sunpower, Inc., fabricated prototype low-cost combustor and magnetic couplings for testing and evaluation and developed low-cost heaters. ORNL and the contractors will use these components in a cost-shared laboratory demonstration with a contractor-supplied free-piston Stirling research engine. DOE completed a 50-percent-cost-shared project with the National Aeronautics and Space Administration on cylinder heat transfer in oscillating flow and pressure conditions.

The Braun linear engine is a free-piston, internal-combustion engine attractive for use in a gas-fired heat pump because of its simplicity and its expected long operational life and low maintenance. DOE completed evaluation of a 15-ton (5.3-kilowatt) system that incorporates the engine, cataloged emissions, and transferred the technology to the private sector.

In preparation for a new program area, micro-cogeneration with fuel cells for residential and commercial buildings, DOE held a workshop in July 1992. The 27 participants, representing R&D organizations, equipment manufacturers, and utilities, defined developmental issues associated with fuel cell technology as applied to buildings. The Department is using the workshop findings in program planning.

Advanced Oil Combustion

Fuel oil provides heat in 12 million American households, 80 percent of which are in the Northeast and Midwest; and up to 500,000 light commercial buildings use similar oil-heating systems. The DOE oil combustion program focuses on upgrading the technology for energy-efficient oil combustion through improved controls and fuel atomization, reduced emissions, and reduced efficiency degradation in relation to fuel quality.

The Flame Quality Indicator, developed by Brookhaven National Laboratory (BNL) researchers and in its third year of field-testing, received an R&D 100 award in 1992 (Figure 1-17). Using a photoconductor and a control circuit, the indicator monitors the brightness of an oil burner flame and signals when the heating unit should be serviced. By recognizing and signaling the existence of a problem in

1-17. The Brookhaven National Laboratory's Flame Quality Indicator improves the energy efficiency of oil-fired heating systems.

its early stages, the indicator helps to maintain peak energy efficiency and reduces the need for expensive repairs. The U.S. Patent and Trademark Office issued DOE a patent for the device in 1992. Energy Kinetics, a manufacturer of hydronic boiler equipment, is commercializing the Flame Quality Indicator, and a Long Island, New York, heating service company is evaluating it for use with multiple fixed-firing-rate boilers in commercial buildings.

The preparation of consumer information and training materials for service technicians is an integral part of the oil combustion program. In December 1992, BNL published guidelines for residential heating system maintenance to minimize problems of fuel oil quality. In 1993, BNL also wrote an oil heat efficiency training manual and developed pilot training courses, completed a computer model for oil-fired venting systems, and drafted venting guidelines for transfer to the private sector.

The 1993 Oil Heat Technology Conference and Workshop, held at BNL on March 25 and 26, 1993, addressed recent technical advances by DOE and industry. This annual meeting has become the principal event for the transfer of technology between researchers and the oil heat

industry; most attendees are oil heat marketers and representatives of industry associations.

Distribution and Controls

The goal of DOE's distribution and controls activities is the development of basic technology and applications for reducing losses from thermal energy distribution systems. Forced air and hydronic systems for distributing HVAC air in buildings are typically only 50- to 60-percent efficient. Losses are caused by duct leakage, induced air infiltration and exfiltration, and other poorly characterized phenomena. Substantial energy savings, reducing thermal losses by half, are possible from improved system design and installation, retrofit, and controls technology; however, these savings are unlikely to be obtained piecemeal.

Duct system losses to unconditioned space in today's typical inefficient residential thermal distribution system account for 20 to 30 percent of the total heating and cooling load on the furnace and air conditioner. An analysis by BNL and LBL showed that long-term national savings of 2 quads (2 exajoules) per year could be achieved, for an annual cost savings of some \$10 billion. DOE initiated development of an efficiency measurement and rating procedure, which will be integrated into the Design for Best Practices program, a new activity in OBT building systems research.

A conference on thermal distribution, held at the National Association of Home Builders headquarters in Washington, D.C., on March 30 and 31, 1992, focused on ways and means to reduce energy loss from inefficient residential heating and cooling air distribution systems. The 90 registrants, from 18 states, represented a cross section of the HVAC industry, Federal and state energy offices, and national laboratories. The conference included presentations by four national trade associations on industry-sponsored standards. Workshops addressed codes, standards, and distribution system efficiency measures; the role of utility demand-side management; and technologies and market forces in retrofit applications and in new construction. BNL published the conference proceedings.

Refrigeration Systems

Refrigeration systems for air-conditioning, heating (heat pumps), and food preservation consume 31 percent of the total electric energy used in buildings. The goal of OBT research activity in refrigeration systems is to develop highly efficient alternative technologies to accelerate the complete phaseout of CFCs (Figure 1-18). These refrigeration systems represent a major source of CFC emis-

1-18. Scientists at Oak Ridge National Laboratory are assessing alternative refrigerants as replacements for CFCs.

sions and other greenhouse gases. Advanced technologies, including new refrigerants and refrigeration systems, can eliminate CFCs and achieve significant energy savings. For example, nonazeotropic refrigerant mixtures can eliminate CFCs and increase energy efficiency by 30 percent, but they require further study of thermophysical properties, development of enhanced heat exchangers, and optimization of the overall system.

A major problem in using alternative refrigerants is their compatibility with the materials and lubricants used in the refrigeration system. Through a multiyear grant, now in its third phase, to the Air Conditioning and Refrigeration Technology Institute, DOE is sponsoring research on the physical properties and materials compatibilities of alternatives to CFC refrigerants and lubricants. Among some 57,000 chlorine-free blends screened as possible alternatives to the commonly used chlorodifluoromethane (CFC-22) refrigerant, researchers identified 400 nonflammable blends for further study, and they completed detailed analyses of the top candidates in 1993. DOE initiated new research projects on the stability and miscibility of alternative

refrigerants and lubricants and on the compatibilities of compressor motor materials, elastomers, and plastics with new refrigerants. These studies will significantly improve the knowledge base upon which new refrigerants and lubricants can be selected, leading to the accelerated acceptance and commercialization of refrigeration systems that use safe alternative refrigerants.

Refrigerant mixtures are the most likely near-term options for replacing ozone-depleting CFCs. The CFC/Slush hydrochlorofluorocarbon (HCFC) ratiometer, developed by ORNL, is a simple device that measures the percentage of each component in a refrigerant mixture. In 1992, the ratiometer won an R&D 100 award for significant new technology. Sensitive to both CFCs and non-CFCs, the device has attracted great interest from industry. It is likely to find applications not only in the laboratory and in factory testing but also at the building site, allowing equipment maintenance personnel to recharge systems with refrigerant without the need for laboratory analysis or complete removal and replacement of the refrigerant. The device is expected to produce consumer cost and energy savings for the installed base of about 80,000 water chillers and thousands of process refrigeration units in the United States.

The Air Conditioning and Refrigeration Institute distributed the latest version of the ORNL Heat Pump Design Model to its members. This computer model evaluates design and operational options for variable-speed-drive compressors and fans, with the goal of performance optimization of current and near-term heat pump technologies. Since the introduction of the first ORNL heat pump model in 1982, more than 200 manufacturers and researchers have used it to cut engineering design time and increase product quality. DOE has a CRADA with E.I. du Pont de Nemours & Company to extend the model to include alternative refrigerant mixtures.

Under a CRADA with DOE, the Alternative Fluorocarbon Environmental Acceptability Study, a research consortium of the world's largest producers of fluorocarbons, released its final report on the potential direct and indirect energy and environmental impacts of CFCs, HCFCs, and near-term alternative refrigerants. As part of the CRADA, ORNL evaluated the relative performance, subsequent carbon dioxide emissions, and net global warming potential of CFC alternatives in building-energy-related applications. The executive summary of the report is an appendix to the United Nations Environment Program's *Technical Options Report on Refrigeration, Air Conditioning, and Heat Pumps*, one in a series of technical documents prepared for use in reevaluating the phaseout requirements for CFCs and HCFCs. The National Insti-

tute of Standards and Technology (NIST), under DOE contract, has completed the preparation of version 4.0 of the REFPROP data base, entitled *Thermodynamic Properties of Refrigerants and Refrigerant Mixtures*. REFPROP is the most popular reference material that NIST publishes. The new version adds nine fluids to the data base and improves predictions for mixtures that contain very polar fluids. Version 4.0 was released in November 1993.

Indoor Air Quality

The energy efficiency of a building and the quality of its indoor air are closely related. Overventilation of a building causes wasteful energy use and increased costs. In addition to reducing the rate of forced air circulation, energy efficiency strategies often increase the airtightness of buildings, thereby reducing the volume of outside air entering the building and reducing the energy required to condition the air. The Nation could save 0.9 quad (0.9 exajoule) per year by the year 2030 by reducing the energy waste associated with air infiltration and inefficient ventilation. However, these strategies may cause a buildup of air pollutants within buildings. Both the National Energy Strategy and EPACT require consideration of indoor air quality (IAQ) in relation to energy efficiency measures.

The DOE Indoor Air Quality Program supports research on the impact of energy efficiency measures on the health and safety of the indoor environment and identifies strategies to avoid such problems. Since its start in the mid-1970s, the program has been responsible for many of the advances in the IAQ field, including the identification of radon gas as a potential health hazard, the development of a computer model to describe air movement in buildings, and the use of tracer gases and scale models to verify and enhance this model. DOE-supported research results can be found in the reference materials and standards of the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE), the American Society for Testing and Materials, and other organizations. Although much of the Department's work has been on commercial buildings, emphasis on IAQ issues in residential buildings is likely to increase.

The Indoor Air Quality Program supports the development of voluntary industry guidelines for infiltration and ventilation. In 1992 ASHRAE issued the proposed "Standard Method of Measuring Air Change Effectiveness" (BSR/ASHRAE 129P) for public review. The standard provides a test method for assessing the IAQ performances

of various ventilation system designs in commercial buildings. DOE-sponsored research contributed most of the scientific and empirical bases for this proposed consensus standard.

A cooperative research program at the National Renewable Energy Laboratory between DOE and the Electric Power Research Institute evaluated a cold air distribution system for cooling large commercial buildings with thermal storage systems. Energy and peak power savings are possible with cold air distribution if performance and comfort problems can be resolved. Typical air distribution systems use air that is 20°F (11°C) colder than room temperature; cold air distribution systems would use temperatures 30°F (17°C) colder than room temperature. Researchers used the imaging and digital analysis system at the National Renewable Energy Laboratory's ventilation research facilities to analyze cold air ventilation jets. Because cold air systems need extra care in specifying the distribution system, the Indoor Air Quality Program developed *Cold Air Distribution Guidelines*, which the Electric Power Research Institute published.

The National Renewable Energy Laboratory is preparing a patent application for a novel concept to improve room air distribution through the use of periodic large-amplitude, low-frequency disturbances to increase mixing and entrainment of a planar jet of air. The technique is promising for retrofit applications as well as for new designs, because the air diffuser itself is not modified.

A new CRADA was initiated with the largest research center in the HVAC industry to use the National Renewable Energy Laboratory expertise and facilities to examine thermal comfort, room air motion, and innovative diffuser performance.

"Sick building syndrome," the unusually high prevalence of health symptoms and health complaints from a building's occupants, is now widely recognized as a significant public health issue. In 1992, LBL completed the California Healthy Building Pilot Study, a multidisciplinary assessment of this phenomenon in large commercial buildings. The results are being used to identify the indoor environmental conditions that produce healthy, comfortable, and productive workplaces.

DOE participates in the quarterly meetings of the Committee on Indoor Air Quality (CIAQ), a legislatively mandated interagency group to coordinate IAQ activities in the Federal sector. CIAQ is cochaired by EPA, DOE, the Consumer Product Safety Commission, the Department of Health and Human Services, and the Occupational Health and Safety Administration. DOE initiated an effort to have CIAQ contribute more substantively to the coordination

of Federal activities in codes and standards related to IAQ. DOE provided a summary report of CIAQ-related activities in codes and standards and initiated consultation on radon construction code recommendations with EPA, as required by EPACT.

Building Systems Research

Buildings are complex, dynamic systems made up of numerous components and subsystems. The energy efficiency of a building depends not only on the individual performances of these components and subsystems but also on their *combined* performance as a system. A building's basic design concepts and features, orientation, and configuration set the stage for what can or cannot be accomplished later in the design process and in the selection and sizing of components and equipment. In addition, subsystems interact in complex ways; for example, the choice of lighting affects the heat load, and hence air-conditioning requirements; daylighting techniques can reduce lighting requirements and provide desired solar gains; and reducing leakage and infiltration can increase ventilation needs. Unfortunately, from the perspectives of energy efficiency, load avoidance, and renewable energy supply, most buildings are not well designed as systems.

The Building Systems Research Program helps industry develop the tools and technologies needed to treat buildings as whole systems. Without the integration of technologies and optimization of the overall building, individual components and subsystems are limited in what they can achieve, and, in a particular installation, they could even be counterproductive. The whole-building systems perspective, from the initiation of new building designs to the retrofitting of existing buildings, is critical to achieving significant energy efficiency and solar contributions from both the overall building and its components and subsystems.

Commercial Buildings

Total use of primary energy in commercial buildings has increased faster than in any other end-use sector over the past two decades. Commercial buildings account for about 15 percent of U.S. primary energy use, with electricity accounting for about two-thirds of the total. Future growth in the electricity demand of commercial buildings could be a major contributor to the supply problems faced by utilities in some regions.

Advanced Commercial Building Technologies

The application of whole-building system considerations to commercial buildings could save 1 quad (1 exajoule) per year by 2030, with an accompanying reduction in electric-generating capacity. The OBT program for advanced commercial building technologies includes the development of computer tools for design and performance evaluation, advanced building systems integration concepts, and the development of whole-building energy targets. DOE will combine these activities in a design-for-best-practices initiative to integrate existing energy design guidelines and handbooks, energy analysis programs, and "expert system" energy-design advisers into commercial software through CRADAs and consortia. These products provide guidance to building designers and utility demand-side management decision-makers in evaluating energy performance and for implementing building energy technologies and integrated design studies.

Computer-aided design offers many opportunities for integrating energy efficiency into the initial design of a building, when it can be done most easily, at least expense, and with maximum benefits. In 1992, the first prototype of the Advanced Energy Design and Operations Technology (AEDOT) software was completed and later displayed at a national trade show. The program will provide design professionals with easy access to the massive amounts of information available on energy-efficient building design. The designer is free to explore ideas on the computer screen, while special tools and "knowledge-based" systems automatically conduct concurrent energy analyses in the background. The prototype resulted from a collaborative effort by developers from California Polytechnic State University (San Luis Obispo) the University of Oregon (Eugene), LBL, and Pacific Northwest Laboratory.

Pacific Northwest has entered into a CRADA with a private firm and the University of Oregon to develop an integrated energy analysis module for computer-aided design software. This project, cofunded with the OBT Industrialized Housing Program, will stimulate the commercialization of DOE technologies by working directly with private industry to integrate a simplified energy analysis capability with a computer-aided design software product developed by the firm, a developer of computer-aided design application software.

DOE began a new program element in 1992 to increase the energy performance of buildings by developing computer-based tools for their commissioning, operation, and control. The Department's strategy is to form a collaboration with the utility industry, control manufacturers, and

HVAC equipment manufacturers to leverage Federal investment and ensure that products are commercialized by industry partners. In a cost-shared effort with the Pacific Gas and Electric Company, the Pacific Northwest Laboratory is exploring the application of advanced diagnostics with building automation systems. These systems assist operators in identifying problems, recommending optimal operating strategies or maintenance, and providing more productive indoor environments.

Stephen Treado of the National Institute of Standards and Technology (NIST) won a national award, presented by the Illuminating Engineering Society of North America, for work cosponsored by OBT and the Electric Power Research Institute on the interaction of lighting and HVAC systems in buildings. Using an experimental facility at NIST, he evaluated various configurations of lighting and HVAC systems for optimal performance and characterized the dynamic thermal interactions between the systems.

Building Energy Performance Simulation

The DOE-2 computer program, originated by OBT more than 10 years ago, is widely recognized for its completeness and accuracy in simulating building energy performance. Given information on a building's location, features, and mode of operation, DOE-2 calculates the hourly energy use and the life-cycle cost of the building. Architects, engineers, and researchers use the program in the design of energy-efficient new commercial and residential buildings, analysis of existing buildings for energy-conserving modifications, calculation of design energy budgets, and cost-benefit analysis of new technologies.

DOE-2 is a public-domain program originally written for mainframe computers. However, private software firms have adapted it for use on microcomputers and are marketing it, along with their own training and support services. In 1992, a third firm began selling the program, which now has thousands of users in the United States and abroad.

DOE-2 has been used in the design of a number of architecturally innovative new buildings and in renovations of historically significant existing buildings. An outstanding recent use has been in the renovation of the Schermerhorn Building in New York City, built in 1891 and now serving as the headquarters of the National Audubon Society. The architect used DOE-2 to create an energy-efficient, ecologically sound, and environmentally safe interior while preserving the historic exterior appearance. In contrast, the Pacific Museum of Flight in Seattle,

Washington, a modern building with semitransparent walls and roof to provide natural lighting for the display of historic aircraft, used DOE-2 to demonstrate that the building met the strict energy code of King County.

Since its introduction, DOE-2 has undergone a number of improvements to add features for modeling additional equipment and modes of building operation. In 1992, the Electric Power Research Institute, along with several member utilities, agreed to cosponsor the development of the next version of the program, DOE-3, including a new user interface. Two major California utilities sponsored focus group workshops in which architects and engineers provided input on the needs and requirements of the program, and LBL produced a videotape on the proposed new energy design adviser. A strong example of the electric utility industry's confidence in the DOE-2 and DOE-3 programs is the Electric Power Research Institute's agreement to replace its own microAXCESS energy analysis tool with DOE-2.

DOE-2 use by electric utilities for the evaluation of demand-side management incentives in buildings is increasing. For example, in 1992 Consolidated Edison Company used DOE-2 to analyze two new Federal buildings in New York City for their energy efficiency potential. As a result, the utility agreed to provide \$2 million in rebates for the resulting demand load reductions.

Residential Buildings

Households use about one-fifth of the primary energy consumed in the United States. The Nation's households had a total energy bill of \$110 billion in 1990, according to EIA's *Household Energy Consumption and Expenditures 1990*, published in February 1993 [DOE/EIA-0321(90)]. Energy costs can be a heavy burden on the monthly budgets of low-income households. Future energy price increases will increase the need and the opportunity for all households to invest in more efficient energy use and in solar and other renewable energy sources.

Energy-Efficient Industrialized Housing

A steady trend in the U.S. homebuilding industry has been the increased use of factory construction. Today, most residential construction incorporates some factory-built components, ranging from simple roof trusses and floor joists, to panelized wall and roof sections, to finished housing modules that are stacked and fastened together at the site, to complete homes that have only to be placed on foundations and connected to utilities. In addition to lower labor costs, industrialized housing offers energy benefits,

through tighter tolerances, improved quality control, and use of materials and fabrication techniques not suitable for site-built construction.

OBT's Industrialized Housing Program focuses on the development of new design tools, manufacturing processes, materials, and construction methods that can improve the energy efficiency and affordability of factory-built housing. Researchers have recently developed computer software capable of simulating and optimizing housing fabrication and assembly processes, and they are currently testing its application in an operational manufacturing facility. In two separate cost-shared research projects, Pennsylvania State University and the Massachusetts Institute of Technology are carrying out research and testing of innovative HVAC and roof designs that can be integrated into factory-built housing.

As a part of DOE's testing and evaluation efforts, in 1992 and 1993, researchers analyzed several industrialized housing factories and, using specially designed instrumentation, measured the energy performance of current industry products. The researchers were able to point out a number of areas where current techniques compromised energy efficiency in the housing and to make recommendations to improve both product quality and energy performance.

DOE is also field-testing advanced housing designs and construction materials to gather real-time data on the performance potential of factory-built components and systems. The University of Oregon has completed the construction of several prototype houses based on a design optimized around factory construction techniques. Performance monitoring of these houses is under way. Another DOE project is measuring two houses, one built with conventional materials and one built with manufactured "foam core" wall panels, at a site near Louisville, Kentucky (Figure 1-19). The Department expects performance testing to document the superior energy performance of the industrialized house.

Advanced Housing Technologies

Advances in construction techniques and products occur more slowly in the U.S. housing industry than in more integrated industries. The Advanced Housing Technology Program is designed to work with the homebuilding industry to accelerate the adoption of energy-conserving technologies. A joint effort with the National Association of Home Builders, which represents 155,000 members who build more than 90 percent of American homes, is identifying new and emerging technologies, developing a plan to encourage their acceptance in the

1-19. The house on the right, which is made with industrialized panel construction, is 15 percent more energy efficient than the otherwise identical house of conventional construction.

marketplace, and developing and implementing a quality improvement program for the U.S. homebuilding industry.

The voluntary National Association of Home Builders program objective is to reduce the heating and cooling requirements of participating homes to half the requirements of new homes built to 1980 standards. Homes constructed under the voluntary program will significantly exceed the energy efficiency required by current local building codes. In 1992, the association's Research Center developed an implementation plan, which was approved in concept by the association's board of directors and is now being considered for adoption by the state homebuilders associations.

Research on Existing Buildings Efficiency

Because buildings are typically used for more than 50 years, improving the energy performance of existing buildings is crucial to national energy efficiency goals. Between 1972 and 1986, improvements to existing buildings increased energy efficiency five times as much as the efficiency contributions of new buildings. The goal of the Existing Buildings Efficiency Research Program is to contribute one-third of the total National Energy Strategy target of 15 quads (16 exajoules) to be saved annually in all buildings by the year 2030. Of this one-third, 3 quads (3 exajoules) will come from residential buildings, and 2 quads (2 exajoules) will come from commercial buildings.

The program supports public- and private-sector efforts to improve the energy efficiency of buildings by developing, validating, and deploying new technology and improved management practices that can significantly increase the energy efficiency of existing buildings. The program also specifically addresses efficiency gains in public and subsidized housing through a joint initiative with the U.S. Department of Housing and Urban Development (HUD).

Retrofit Technologies

DOE is developing integrated retrofit packages, consisting of advanced diagnostics, retrofit methods, and effective products, to achieve energy savings of 50 percent or more in existing building stock, using current and emerging materials and technologies. In 1992, retrofit monitoring protocols were developed for publication as a chapter in the *ASHRAE Handbook of Fundamentals* and as American Society for Testing and Materials recommended practices.

Oak Ridge National Laboratory has developed the National Energy Audit, a heating and cooling audit for the Office of Technical and Financial Assistance's Weatherization Assistance Program, in cooperation with states and utilities and is now testing it in the regions. The audit method emphasizes the interaction of retrofit measures. The laboratory is also adapting the audit for use in middle-income residential units.

DOE developed a new cooperative program on military family housing with the Federal Energy Management Program (FEMP) and the Department of Defense Tri-Services. The program has been initiated with the commitment of funds from the U.S. Air Force and the U.S. Army. The objective is to obtain the optimum level of energy efficiency during major rehabilitation and energy retrofit of existing military family housing. The program will integrate state-of-the-art technologies and diagnostic procedures into the design, specification, and inspection phases of military projects. The program will implement advanced technologies at four to eight military installations and compare those technologies with conventional rehabilitation methods through the monitoring of energy savings. ORNL will develop a design guide, targeted to the architect-engineering firms that complete the detailed design and specifications of projects, and an inspection guide for use by military personnel, architects and engineers, and other contractors. The guides will apply to both existing and new housing construction.

DOE-Department of Housing and Urban Development Initiative

The DOE-HUD Initiative is designed to improve the energy efficiency of public and other types of federally assisted housing, with the goal of saving 0.15 quad (160 petajoules) per year, or nearly \$1.5 billion in energy costs. With a strong framework for technical and institutional cooperation among DOE's national laboratories and support offices and HUD's regional offices and local authorities, the initiative has undertaken model demonstration projects, provided training to public housing staff, and demonstrated how to integrate weatherization and property rehabilitation resources along with utility incentives for energy efficiency upgrades. Begun in 1990, the initiative is now in the last of its scheduled 4 years, and DOE is conducting an evaluation to measure its effectiveness.

Demonstrations of model energy efficiency retrofits extended to all 10 DOE regions in 1993. The purpose of the demonstrations is to document the experiences gained from conservation techniques, financial management procedures, and public-private partnership options. The demonstrations are being conducted with the DOE support offices, with 50-percent cost sharing with HUD and the utilities. For example, in 1992 a 13-story, 150-unit apartment building in Chelsea, Massachusetts, received energy-efficient lighting, replacement windows, and air-handling equipment retrofit options identified by DOE. Boston Edison Company provided funding through its demand-side management program.

DOE completed a number of field studies on the effectiveness of specific retrofit technologies and methods. LBL completed a study on the effectiveness and persistence of energy savings after retrofits at 40 different housing sites. The study showed that in major rehabilitation projects, good operating and maintenance practices for the new equipment are critical if the energy savings are to last more than 3 to 4 years.

A new guidebook published in February 1992 and prepared by ORNL, *Energy Performance Contracting for Public and Indian Housing: A Guide for Participants*, represents a major milestone under the DOE-HUD Initiative. This guidebook provides a clear and cogent discussion of practical methods for alternative financing of energy efficiency improvements—a critical first need for public housing. The format and publication process set important precedents for future publications that will be produced from the initiative.

The first Energy Performance Contracting Workshop was held in Boston, October 27 to 29, 1992, with 45 public housing authorities participating. Specific objectives of the workshop are to train a public housing authority in proce-

dures to select an energy service company, to prepare the authority for negotiating a performance contract with the energy service company selected, and to assist the authority and field and regional HUD offices in learning the new approval requirement for performance contracts.

The initiative also took a number of steps to assist with the problem of the homeless. A guidebook for shelter providers, *Energy Conservation in Housing for the Homeless*, was published in January 1993. In another DOE-HUD Initiative project, HUD houses are being used to house the homeless in Philadelphia. Rehabilitation of the properties will be carried out by the Philadelphia Housing Development Corporation, with funding provided by DOE, from the Weatherization Assistance Program and the Existing Buildings Efficiency Research Program, and by the city's HUD Community Development Block Grant program. Acting through the Federal Interagency Council on the Homeless, up to 50 HUD properties will be made habitable for use by nonprofit providers of assistance to the homeless. HUD will provide these single-family properties at an annual lease of \$1 per property per year, extendable up to 5 years. In Chicago, transitional housing of the homeless in two identical 15-unit apartment buildings was upgraded for energy efficiency with DOE-HUD Initiative and other funds. One building was done as a standard Community Development Block Grant rehabilitation project, and the other was a superinsulated Illinois Energy Office project, with technical assistance from the University of Illinois. Monitoring of utility use in both buildings over 1 year will allow a side-by-side comparison of savings, to validate the savings claimed in other buildings under the superinsulation program. The results will also demonstrate the benefit of revising HUD regulations to require an energy retrofit at the time of rehabilitation.

Building Standards and Guidelines

Appliance Standards

The Appliance Standards Program, a regulatory component of OBT, implements legislative mandates on energy conservation for new residential and commercial appliances. The Energy Policy and Conservation Act requires DOE to develop test procedures for measuring the energy efficiency of major household and commercial appliances and to analyze the need to amend the act's efficiency standards. As an example of the potential of energy efficient appliances, Figure 1-20 shows the past and projected energy savings from increasing the efficiency of refrigerators.

1-20. Past and projected improvements in the energy efficiency of refrigerators, 1970-2010.

In 1992 the Appliance Standards Program continued several rulemaking proceedings to carry out the legislated requirements. For example, DOE completed its analysis of a proposed standards rulemaking for room air conditioners, water heaters, direct heating equipment, mobile-home furnaces, kitchen ranges and ovens, pool heaters, fluorescent-lamp ballasts, and television sets, as well as the technical support document. Also, the Department completed an advance notice of proposed rulemaking for the first review of the standard levels for furnaces and boilers and central air conditioners and heat pumps, and the second review of the standard levels for refrigerators and freezers.

In the area of test procedures, DOE continued research for all products and completed a proposed rule amending the test procedures for furnaces and boilers, vented home heating equipment, and pool heaters. The Department granted 13 interim test procedure waivers in response to

manufacturer requests for alternative test procedures for new, more efficient furnaces, and 1 for central air conditioners. Also published was a small-business exemption from the standard for single-package air-conditioning systems.

During 1992 the Department completed a report that reviewed options for a commercial building relighting initiative. The report documented the energy savings possibilities from several potential Federal actions. The study became part of the Department's National Energy Strategy, and its results are reflected in the lighting standards in EPACT.

EPACT adds significant new responsibilities to the Appliance Standards Program. Commercial HVAC equipment and some lighting and plumbing products are brought under the program for the first time. EPACT establishes standards for many of these products, as well as the means for increasing the stringency of these legislated standards.

In addition to its direct impacts, the Appliance Standards Program helps to develop and exchange beneficial technology between OBT and the private sector. DOE staff participate with ASHRAE in the development of standards, test procedures, and technical research and also serve as members of ASHRAE committees on appliance energy efficiency measurement techniques.

Building Standards and Guidelines

DOE's Standards and Guidelines program focuses on reducing the energy demand of the Nation's building stock and on increasing the use of renewable energy to help meet that demand. As required by the Energy Conservation Standards for New Buildings Act of 1976, as amended (42 U.S.C. 6831 et seq.), the Department has developed energy conservation standards for various categories of buildings. These standards can be adopted by reference, codified with Federal, state, and local building codes or regulations, or used by prospective building owners in setting energy consumption requirements for new buildings. The standards for new building design set technically feasible criteria that will result in cost-effective buildings that are significantly more energy efficient than those currently under construction.

In 1992, the Department completed assessments of the impacts of its interim energy conservation standards for both Federal residential buildings and commercial buildings and reported the results of the demonstration to Congress. The assessment for the residential building standards showed that the standards are technologically feasible and economically justified; that the standards adapt well to Federal procurement and design processes; that the standards reduce Federal housing costs, including first cost and energy costs; and that they have no impact on low- and moderate-income consumers. The most significant and unexpected finding was that because Federal agencies often pay relatively low fuel and energy prices, life-cycle cost analyses eliminate many common energy efficiency measures as not being cost-effective.

The assessment of buildings designed to the commercial and multifamily highrise standards was that they are equivalent or lower in construction cost relative to buildings designed to the most broadly adopted energy standard, standard 90A-1980. The analysis also concluded that the standards will have no adverse impact on builders or the ability of low- to moderate-income people to rent or purchase units in multifamily highrise buildings constructed to the standards. Over all building types, the average building designed to the standards should

expect a 13-percent reduction in energy costs when using 1989 lighting criteria, and an 18-percent reduction when using 1993 lighting criteria. The standards criteria focus on no specific fuel type, but as the largest energy use reduction is from lighting and cooling, a significant portion of the reduction will occur in electricity use. The analysis also showed that recent advances and emerging technologies could significantly improve the next generation's standards. The report concluded that the standards or their equivalent (ASHRAE/IES standard 90.1-1989) should be promptly adopted by model code organizations and state and local code jurisdictions, as well as by Federal agencies as criteria for buildings covered under federally assisted loans and loan guarantees and for public housing.

The Department has monitored the progress made by state and local governments in adopting and enforcing energy efficiency standards for new buildings, identified procedural obstacles to implementation, and determined how to evaluate the effectiveness of such standards. As of the fall of 1992, DOE found that the majority of state and local government programs did not yet reflect the national energy standards' initiatives, but that progress was under way to update codes in more than 10 states. The Department found that knowledge about code enforcement and effectiveness of standards was fragmentary and anecdotal. The Department defined potential obstacles to adoption and it will use them to assess how state adoption and enforcement programs are functioning and to identify areas where additional implementation assistance is needed.

In August 1992, DOE proposed voluntary guidelines or model standards appropriate for adoption by state and local governments that update their current codes. The standard provides three alternative compliance approaches:

1. *Component prescriptive*: Specifies easily used, inflexible criteria, such as R-19 wall insulation
2. *Point system*: Requires calculations, but provides some flexibility—for example, more effective insulation for less efficient equipment
3. *Building performance*: Requires building energy analysis, but allows wide flexibility in energy conservation measures used

The standard also provides a user-friendly computer program designed to assist state and local officials in tailoring the standards to their region or locale.

In response to section 101 of EPACT, DOE refocused and expanded the Standards and Guidelines program to

(1) provide technical assistance to help states upgrade their building energy efficiency codes so they meet or exceed the 1992 Model Energy Code for residential buildings and standard 90.1–1989 for commercial buildings, (2) make Federal standards and voluntary building energy codes more similar and include appropriate measures to address radon and other indoor pollutants, and (3) support the upgrading of voluntary commercial and residential building energy codes.

To this end, in 1992, DOE provided guidance to states on upgrading their standards, the certification of those actions, anticipated technical assistance, and incentive funding. Limited technical assistance was provided to a few states. The Department also proposed modifications to the 1989 Model Energy Code, and in 1993 it proposed modifications to its successor, the 1992 Model Energy Code. Both proposals were based on analyses developed in conjunction with the voluntary residential standards effort. In addition, DOE helped ASHRAE complete its voluntary residential lowrise energy standard, standard 90.2–1993. The Department expects to use standard 90.2–1993 as the basis for proposing a major upgrade to the Model Energy Code to be published in 1995. In 1993, DOE also supported the development of a user's manual for ASHRAE/IES standard 90.1–1989 and a codified version of that standard. Both efforts are aimed at facilitating the adoption and implementation of standard 90.1–1989 by the model codes and state and local governments.

FEDERAL ENERGY MANAGEMENT PROGRAM

The Federal Energy Management Program (FEMP) expanded its efforts in 1992 to help agencies implement Executive Order 12759, which directs the Federal Government to demonstrate a leadership role in energy efficiency in Federal buildings, operations, and vehicle fleets. When it passed EPACT, Congress reaffirmed the Federal Government's commitment to achieve 20-percent energy savings by the year 2000 (Figure 1–21). EPACT provides FEMP with additional tools and responsibilities that will be implemented in 1993.

In 1991, the Federal Government consumed 1.46 quads (1.54 exajoules) of energy (at site of use) in its buildings and operations at a cost of \$11.28 billion, representing 0.85 percent of all Government expenditures. The increase from \$9.9 billion in 1990 is directly attributable

to expanded fuel use for Operation Desert Storm. Expenditures for building energy fell from \$4.0 billion in 1990 to \$3.76 billion in 1991, a decrease of 4.9 percent from the 1985 level. The Federal Government remains the largest energy user in the Nation, consuming 2.4 percent of all energy used in the country. The Government has the opportunity to dramatically reduce its energy use and, if the 20-percent reduction goal were achieved, could cumulatively save \$1 billion by the year 2000 over 1985.

Established in response to the oil embargo in the mid-1970s, FEMP provides guidance and technical assistance to Federal energy managers to support their efforts to reduce energy use within their agencies. Executive Order 12759 and EPACT have increased attention on energy efficiency and have begun the process of substantively addressing energy use in the Federal Government's buildings and operations.

In 1992, FEMP worked to implement Executive Order 12759, with extensive cooperation from the Federal Interagency Energy Management Task Force. The Federal agencies have developed and submitted plans to address energy use in their buildings and vehicles. To reduce energy costs in their buildings, agencies plan to use shared energy savings and utility-based demand-side management programs. In addition, they have outlined their plans to purchase alternative-fueled vehicles.

The first application of the Test Bed Demonstration Program is testing a natural-gas cooling system. DOE (through Pacific Northwest Laboratory), the Thermo King Corporation, Willow Grove Naval Air Station, Philadelphia Electric Company, and the American Gas Cooling Center joined in a CRADA to test the efficiency of two gas-powered rooftop air-conditioning units developed by Thermo King. The units were selected through a cost analysis of six system options conducted by the Naval Facilities Engineering Command in Philadelphia, Pennsylvania. The analysis concluded that the natural-gas system would provide the best return on investment, with a projected savings in annual operating costs of more than \$8,000. To demonstrate the technology, the Willow Grove Naval Air Station retrofitted the Exchange Building—a 1st-story, 18,000-square-foot (1,700-square-meter) masonry structure—with two cooling units. The station also equipped the building with a system to collect performance data. DOE published and distributed an analysis of the data in 1993.

FEMP expanded its technical assistance through training courses conducted throughout the country, entitled "Shared Energy Savings for Federal Agencies," "Life-

I-21. Although Federal buildings have improved their energy efficiency considerably, further efforts are required to meet the goals of EPACT and Executive Order 12759.

Cycle Costing/ASEAM," "Integrated Energy Management/Federal Energy Decision Screening," and "Energy-Efficient Lighting for Federal Agencies." The program completed tools and procedures to implement the Federal Relighting Initiative.

FEMP implemented its first large-scale demonstration project using demand-side management and shared energy savings. The Fort Lewis, Washington, project serves as a model program for large Federal facilities. The project's partnership of Tacoma Public Utilities, Bonneville Power Administration, and the Army will allow Fort Lewis to install more than \$10 million of life-cycle cost-effective lighting and motor technologies, with no up-front Federal expense or capital outlay. The utility will finance the project through a shared energy savings plan and pay 85 percent of the cost of the

project, with the Army paying 15 percent over the life of the project.

Shared energy savings activity in 1992 grew to 12 active contracts, representing an investment of \$42 million in private-sector funds. With energy-saving-performance contract provisions in EPACT, FEMP will prepare a how-to guide and a model solicitation to increase the use of private capital to help achieve Federal agency goals.

The annual Federal Energy Awareness Awards recognized 30 outstanding Federal energy managers and their agencies. Agencies around the world submitted a record number of proposals. In 1992, DOE initiated a renewable energy award. With EPACT authorization for cash incentives for outstanding Federal energy managers, FEMP is preparing a nomination process for 1993 that offered this special incentive to facility managers.

TECHNICAL AND FINANCIAL ASSISTANCE

Introduction

The accelerated and widespread adoption of renewable energy and energy efficiency technologies and practices is fundamental to achieving the Administration's economic and environmental goals. The benefits extend beyond pollution abatement, reduction in global warming, enhanced energy security, and improved trade balances; they also include job creation and improved productivity and competitiveness for U.S. industry. The objective of rapid and widescale technology deployment requires coordinated action among Federal, state, and local governments and their private-sector partners.

The Office of Technical and Financial Assistance operates a comprehensive array of grant, information, and technical assistance programs to support increased energy efficiency and renewable energy use in the public, private, and nonprofit sectors. These programs operate through, or in partnership with, state and local governments, industry and trade associations, nonprofit organizations, and other Federal agencies, and both domestic and international energy users and markets. The well-developed delivery systems and networks that serve Office of Technical and Financial Assistance programs provide an excellent base for both immediate and longer range technology demonstration and transfer.

In particular, the diversity among states and their role within our Federal system require that they have a major involvement in the development and execution of national energy policies. Energy use among the end-use sectors varies substantially from region to region and from state to state (with such factors as economic base, climate, building stock, transportation, and other infrastructure); fuels use within each sector varies even more dramatically. States are closer than the Federal Government to many issues, problems, and constituencies, and they have many regulatory and other powers reserved to them. They are also well positioned to serve as laboratories for testing and demonstration of new DOE-developed technologies. They can provide valuable focus for—and input to—DOE's research agenda; and they represent a significant source of energy-related R&D that merits sharing.

EPACT stresses the deployment of alternative fuels (including renewable energy) and energy efficiency technologies and practices, and it provides for a strong state role in this process. With respect to Office of Technical and Fi-

nancial Assistance state grant programs, EPACT is likely to accelerate the trend toward cooperative, cost-shared, targeted technology demonstration and deployment projects. The ability to undertake these joint DOE-state activities rests on the maintenance of a strong core program structure.

In addition to its grants administration, information and technology transfer, and domestic and international marketing responsibilities, the Office of Technical and Financial Assistance provides oversight for programs and projects carried out by states with funds received under the terms of the court settlements of the Exxon and Stripper Well petroleum pricing violation cases. Tables 1-2a, 1-2b, 1-3a, and 1-3b show state receipts and expenditures of these funds through 1992 and 1993, respectively.

State Energy Conservation Program

The State Energy Conservation Program's (SECP) congressional mandate is to promote energy efficiency, reduce the growth of energy demand, and provide technical and cost-shared financial assistance to 50 states, 6 U.S. territories, and the District of Columbia. The recipients of this assistance develop and implement comprehensive plans for achieving specific energy goals appropriate to their individual needs.

Early in its history, SECP concentrated on five mandatory measures, which ranged from promoting carpools and enacting right-turn-on-red legislation to implementing lighting and thermal efficiency standards for non-Federal public buildings. Over time, the program increasingly focused on optional measures as the mandatory measures were implemented and additional sources of funding became available (largely in the form of petroleum violation escrow moneys). Additional legislation and regulatory amendments built increasing flexibility into the program, and states responded by developing and funding activities that are innovative, responsive to the need to leverage resources, and supportive of the Nation's need to intensify its energy efficiency efforts.

Services

SECP funding and guidance help establish and expand state capabilities to plan, design, and implement activities that lead to more efficient uses of energy and reduce the growth of energy demand (Table 1-4 lists the 1992 and 1993 grant funds by state).

Table 1-2a—Exxon petroleum violation fund expenditures as of September 30, 1992

State	Total received	Expenditures					Total ^a
		State Energy Conservation Program	Energy Extension Service	Weatherization Assistance Program	Institutional Conservation Program	Low-Income Home Energy Assistance Program	
		(millions of dollars)					
Alabama	39.4	7.6	3.3	3.1	8.9	6.4	29.2
Alaska	11.0	1.4	1.2	6.6	0.6	0	9.7
American Samoa	0.4	0.3	0	0	0	0	0.4
Arizona	31.6	6.1	0.4	4.7	1.0	2.1	14.1
Arkansas	31.8	3.2	0.2	3.9	10.7	5.0	23.0
California	249.8	50.4	12.0	0	0.6	69.3	132.4
Colorado	30.7	10.3	0	5.5	0	0	15.9
Connecticut	43.4	2.0	3.0	0	0.3	34.9	40.2
Delaware	14.1	0.2	0	3.3	6.8	0.5	11.0
District of Columbia	5.3	1.4	0.5	0.8	0.4	0.9	4.0
Florida	139.7	27.6	0	0.2	34.5	0	62.4
Georgia	58.6	1.3	2.4	14.0	9.8	21.0	48.5
Guam	4.5	1.3	0	0	0.2	0	1.5
Hawaii.....	18.6	6.9	2.0	3.5	1.6	0	14.0
Idaho	13.0	4.2	0	3.2	1.1	0	8.5
Illinois	122.3	11.8	4.0	59.7	0	45.0	120.5
Indiana	63.8	8.5	2.1	0	0.4	37.5	48.6
Iowa	35.7	9.3	5.0	12.6	0	0	26.9
Kansas	31.3	2.8	0.4	3.6	6.0	16.2	29.0
Kentucky	35.6	0	0	16.0	0	7.1	23.1
Louisiana	75.3	3.4	3.1	11.4	3.6	0	21.5
Maine	17.9	6.4	1.2	7.6	1.2	0.7	17.2
Maryland	41.5	0.8	1.2	29.1	2.3	4.4	38.0
Massachusetts	84.0	20.9	0	42.2	0	20.5	83.6
Michigan	81.6	20.3	0	13.0	0	48.0	81.4
Minnesota	45.7	27.9	4.8	5.7	0	6.2	44.6
Mississippi	33.1	9.6	1.0	7.9	7.6	2.1	28.1
Missouri	52.0	11.2	0.5	17.0	8.8	3.1	40.6
Montana	11.4	3.1	0.3	5.1	1.4	0	9.9
Nebraska	22.9	12.4	1.3	3.0	0	0	16.8
Nevada	11.8	0.8	1.8	3.3	0.3	5.1	11.3
New Hampshire	12.7	6.2	2.7	1.3	0.1	0.6	11.0
New Jersey	104.2	0.1	0	0	7.9	68.1	76.1
New Mexico	17.6	3.1	1.1	7.1	1.2	4.6	17.0
New York	213.0	55.8	18.0	45.5	12.0	17.8	149.2
North Carolina	70.3	8.7	1.0	17.5	3.8	15.6	46.7
North Dakota	9.9	1.4	0.1	1.0	2.5	2.8	7.8
Northern Mariana Islands	0.3	0.2	0	0	0	0	0.2
Ohio	106.4	7.9	1.8	67.6	4.2	16.6	98.2
Oklahoma	33.5	8.6	1.6	6.6	3.0	6.8	26.6
Oregon	24.7	6.3	0.3	13.7	0	2.8	23.1
Pennsylvania	111.5	5.0	0.8	22.8	4.6	76.7	109.9

Table 1-2a—Exxon petroleum violation fund expenditures as of September 30, 1992 (continued)

State	Total received	Expenditures					Total ^a
		State Energy Conservation Program	Energy Extension Service	Weatherization Assistance Program	Institutional Conservation Program	Low-Income Home Energy Assistance Program	
		(millions of dollars)					
Puerto Rico	24.3	1.2	0.1	0	1.1	20.0	22.3
Rhode Island	10.4	3.4	1.6	1.3	1.2	0.2	7.7
South Carolina	34.6	3.9	0.2	2.8	1.4	9.4	17.9
South Dakota	10.2	5.0	0.2	0.3	0.3	1.3	7.1
Tennessee	47.3	4.9	0.8	22.3	7.8	7.5	43.2
Texas	221.3	27.3	3.6	11.1	2.9	9.1	53.9
Trust Territories	0	NA	NA	NA	NA	0	0
Utah	17.1	2.9	0.5	7.0	1.8	0	12.3
Vermont	6.3	2.1	0	2.6	0	0.8	5.4
Virgin Islands	13.1	6.0	0	0	0	0	6.1
Virginia	67.6	5.8	0.7	31.4	3.6	26.1	67.6
Washington	44.5	18.1	0.7	16.3	0	1.5	36.6
West Virginia	15.8	2.2	0.2	3.2	0.3	7.4	13.3
Wisconsin	51.0	0.3	0.2	32.8	0	2.6	35.8
Wyoming	12.6	0	0	2.8	0.2	0	2.9
Total ^a	2,738.0	459.8	87.9	603.0	168.0	634.1	1,953.8

^a Due to rounding, total may not be exact. NA = Not applicable. [Correct?]

In addition to providing direct financial assistance to the states, in 1992 and 1993 DOE continued to provide technical assistance by various means, including developing an information clearinghouse and retrieval capability, producing and distributing training materials, conducting seminars and workshops, and offering coordination and liaison services. These activities provided opportunities for the interstate exchange of information and technical expertise.

At the annual National Program Managers' Conference for the State Energy Conservation Program, the Schools and Hospitals Program, and the Energy Extension Service, sponsored by DOE, state program managers studied such topics as utility-state joint ventures, alternative transportation fuels, municipal conservation activities, energy efficiency in state facilities, and building partnerships with the environmental community. DOE also provided technical assistance through peer exchange at regional conferences. The Office of Technical and Financial Assistance's *Conservation Update*, a monthly newsletter

distributed to all state energy offices, described new and innovative projects being conducted in each state and listed available publications and other materials, such as videotapes.

State Activities

The following programs are typical of SECP activities implemented at the state level during 1992 and 1993. The states conduct these programs in accordance with DOE program regulations and with oversight provided by DOE support offices.

Alabama

Project ROSE (Recycled Oil Saves Energy) educates the public about recycling used oil, helps establish used oil recycling programs, and offers used oil collection and recycling assistance in Alabama. Project ROSE continually recruits new used motor oil collection centers, such as oil

Table 1-2b—Exxon petroleum violation fund expenditures as of September 30, 1993 (million dollars)

State	Total received	Expenditures					Total ^a
		State Energy Conservation Program	Energy Extension Service	Weatherization Assistance Program	Institutional Conservation Program	Low-Income Home Energy Assistance Program	
Alabama	39.3	7.9	3.8	3.2	9.7	9.7	34.3
Alaska	11.0	2.0	1.2	6.6	0.6	0.0	10.4
American Samoa	0.4	0.3	0.0	0.0	0.0	0.0	0.3
Arizona	30.4	9.2	0.4	5.1	1.4	2.6	18.7
Arkansas	33.6	4.0	0.2	4.5	17.8	4.8	31.3
California	264.0	115.4	13.8	0.0	2.6	82.6	214.4
Colorado	31.6	13.0	0.0	5.6	0.0	0.0	18.6
Connecticut	43.5	2.1	3.1	0.0	0.4	35.5	41.1
Delaware	14.4	0.3	0.1	3.6	7.5	0.8	12.3
District of Columbia ..	6.0	1.8	0.6	0.9	0.4	0.2	3.9
Florida	149.0	35.4	0.0	0.2	47.6	0.0	83.2
Georgia	57.8	1.3	2.4	15.2	11.7	21.0	51.6
Guam	4.7	1.7	0.0	0.0	0.2	0.0	1.9
Hawaii	18.7	7.7	2.1	4.2	1.6	0.0	15.6
Idaho	10.5	4.3	0.0	3.2	1.2	0.0	8.7
Illinois	122.5	11.9	4.0	59.7	0.0	45.0	120.6
Indiana	64.2	8.5	2.1	0.0	0.4	45.5	56.5
Iowa	36.2	9.7	5.3	15.7	0.0	0.3	31.0
Kansas	31.4	2.8	0.4	4.2	5.1	16.3	28.8
Kentucky	35.6	0.0	0.0	18.9	0.0	7.1	26.0
Louisiana	77.1	5.2	4.7	11.5	4.7	0.0	26.1
Maine	17.4	6.4	1.5	7.6	1.2	0.6	17.3
Maryland	43.7	0.9	1.2	30.0	3.0	5.4	40.5
Massachusetts	84.0	20.9	0.0	41.8	0.0	20.5	83.2
Michigan	81.6	20.4	0.0	13.0	0.0	47.6	81.0
Minnesota	45.7	27.9	4.8	5.7	0.0	6.2	44.6
Mississippi	32.4	10.0	1.1	7.9	8.5	2.2	29.7
Missouri	52.7	11.9	0.5	17.0	9.8	3.1	42.3
Montana	12.0	3.2	0.3	5.3	1.5	0.8	11.1
Nebraska	23.2	14.3	1.4	4.0	0.0	0.0	19.7
Nevada	11.4	0.8	1.9	3.3	0.3	5.0	11.3
New Hampshire	12.7	6.4	2.9	1.3	0.1	0.7	11.4
New Jersey	96.8	0.3	0.0	0.0	9.0	68.8	78.1
New Mexico	17.6	3.2	1.3	7.1	1.2	4.6	17.4
New York	215.2	61.5	18.6	45.5	15.3	19.0	159.9
North Carolina	71.8	10.6	1.4	18.8	4.9	16.9	52.6
North Dakota	10.0	1.4	0.1	1.0	2.8	3.3	8.6
Northern Marianas ...	0.3	0.2	0.0	0.0	0.0	0.0	0.2
Ohio	108.2	7.3	1.8	67.4	4.8	16.6	97.9
Oklahoma	33.7	10.9	1.7	6.7	3.4	7.0	29.7
Oregon	25.3	6.7	0.3	14.0	0.0	3.5	24.5
Pennsylvania	112.5	5.0	0.8	22.8	4.6	79.3	112.5
Puerto Rico	24.3	1.5	0.1	0.0	1.1	20.0	22.7
Rhode Island	10.5	4.3	1.6	1.3	1.3	0.0	8.5
South Carolina	35.0	5.7	0.5	3.1	3.2	11.0	23.5
South Dakota	10.2	6.2	0.2	0.3	0.5	1.3	8.5

Table 1-2b—Exxon petroleum violation fund expenditures as of September 30, 1993 (million dollars) (continued)

		Expenditures					
State	Total received	State Energy Conservation Program	Energy Extension Service	Weatherization Assistance Program	Institutional Conservation Program	Low-Income Home Energy Assistance Program	Total ^a
(millions of dollars)							
Tennessee	35.0	5.7	0.5	3.1	3.2	11.0	23.5
Texas	227.0	54.0	5.5	16.4	7.3	16.6	99.8
Utah	17.3	4.0	0.6	7.4	2.0	0.0	14.0
Vermont	6.3	2.2	0.0	2.6	0.0	1.1	5.9
Virgin Islands	14.4	8.2	0.5	0.0	0.0	0.3	9.0
Virginia	68.0	5.8	0.7	32.5	4.0	27.0	70.0
Washington	40.8	19.2	0.7	16.5	0.0	1.5	37.9
West Virginia	15.8	2.3	0.2	3.2	0.4	7.4	13.5
Wisconsin	53.7	0.8	0.4	38.1	0.0	4.7	44.0
Wyoming	14.6	1.1	0.0	4.3	0.4	0.0	5.8
Total ^a	2,763.0	595.7	97.3	611.3	206.7	684.4	2,195.4

Note: Total received includes interest reported to date.

^aBecause of rounding, totals may not be exact.

retailers, auto part stores, full-service gas stations, and quick lubrication and oil facilities. SECP has sponsored this program for 14 years; with help from EPA, Project ROSE is now helping the Walt Disney World Company to establish a used oil recycling program for its 35,000 employees. Project ROSE has built an extensive infrastructure for recycling used automobile oil generated by do-it-yourselfers. The program provides education and publicity to start local used oil recycling programs and then coordinates the efforts of established networks by matching buyers of used oil with collectors. This strategy relies heavily on recruiting leaders from local organizations who then work with Project ROSE to help introduce and support a recycling program in their area.

Massachusetts

The Energy Advisory Service of the Massachusetts Department of Energy Resources works to increase the competitiveness of Massachusetts industries by providing customized engineering analyses to identify profitable energy efficiency improvement opportunities. The service has assisted more than 400 firms and identified more than

\$60 million in annual cost savings, averaging a simple payback of 2.02 years for the opportunities selected. The Department of Energy Resources contracts with private-sector engineering firms that can provide energy management expertise, are familiar with a range of industrial processes, are able to conduct site analyses, and can make solid presentations on their findings. The department's staff coordinate all aspects of each project, including client recruitment, selection of advisers, and definition of project scope (with input from the engineering firm and the client), and act as the liaison with utilities on potential load management programs. The Energy Advisory Service was instrumental in saving a large frozen-dessert plant (Kraft-Sealtest in Framingham, Massachusetts) from closing by identifying opportunities for savings of nearly \$300,000 in energy costs. The local utility agreed to finance \$3.3 million of the \$3.6 million required to renovate the facility's refrigeration system.

New Mexico

While planning a number of capital improvement projects, the city of Albuquerque, New Mexico, found that several

Table 1-3a—Stripper Well petroleum violation fund expenditures as of September 30, 1992

State	Expenditures							Total ^a
	Total received	State Energy Conservation Program	Energy Extension Service	Weatherization Assistance Program	Institutional Conservation Program	Low-Income Home Energy Assistance Program	Other	
		(millions of dollars)						
Alabama	30.6	0.1	0.6	0	0.6	2.3	17.4	21.0
Alaska	8.9	0.3	0	0	0	0	0.9	1.2
American Samoa	0.3	0.2	0	0	0	0	0	0.2
Arizona	21.9	0.1	0	0	0	0.9	7.9	8.9
Arkansas	23.2	0	0	2.9	0	1.9	8.6	13.4
California	175.2	0	0	0	0	25.5	76.1	101.6
Colorado	21.8	1.7	0	4.6	0	0	0.6	6.9
Connecticut	33.2	0	0	0	0.2	8.8	15.3	24.3
Delaware	9.9	0	0	1.5	0	0.2	6.0	7.7
District of Columbia	4.6	0	0.3	0	0	0	1.3	1.5
Florida	92.6	0.8	0	20.4	1.1	0	23.6	45.9
Georgia	42.2	4.0	2.9	0	0	6.7	12.6	26.1
Guam	3.5	0.8	0	0	0	0	0	0.8
Hawaii	14.8	1.7	0.2	0	0	0	0.8	2.8
Idaho	7.9	0	0	0.1	0	0	5.5	5.6
Illinois	89.6	0	0	0	0.2	11.5	33.4	45.1
Indiana	46.2	0.4	0.5	0	0	2.3	28.1	31.3
Iowa	26.5	0	0	0	0	0	16.6	16.6
Kansas	23.3	0.4	0.1	1.3	0	0.9	8.2	11.0
Kentucky	25.3	0	0	0	0.5	7.8	0.6	8.9
Louisiana	45.8	0.2	2.4	0	0	0	20.9	23.5
Maine	15.7	2.5	0.7	0	0.4	3.5	2.7	9.9
Maryland	34.0	0.7	0.3	8.3	0	15.9	4.6	29.8
Massachusetts	70.8	10.0	0.2	0	0	11.1	27.6	48.9
Michigan	67.9	1.4	0	15.4	0	17.6	28.9	63.4
Minnesota	36.2	0	0	13.9	0	0	13.9	27.8
Mississippi	33.9	0.8	2.0	1.9	0	1.1	7.1	10.8
Missouri	41.5	0.6	0	6.7	0	0	4.9	12.2
Montana	8.7	0.3	0.3	1.3	0.3	0.6	0.8	3.6
Nebraska	15.9	0	0	0.6	0	0	7.0	7.7
Nevada	7.7	0.1	0.1	0.4	0	1.1	4.4	6.1
New Hampshire	9.2	0.5	0.4	1.5	0	0.3	0.4	3.2
New Jersey	82.1	0	0	0	0	7.1	14.0	21.1
New Mexico	13.9	0.1	0	1.6	0.5	0	7.0	9.2
New York	167.3	3.8	0	21.8	0.4	0	46.3	72.3
North Carolina	54.4	0	0	0	0	0	18.6	18.6
North Dakota	7.6	0.2	0	0	0	1.3	2.8	4.3
Northern Mariana Islands ..	0.2	0.1	0	0	0	0	0	0.1
Ohio	83.1	0.4	0.6	10.3	0	0	39.8	51.1
Oklahoma	23.3	0	0	0	0	1.1	15.5	16.6
Oregon	19.1	0.2	0.2	0	0	0	15.4	15.8
Pennsylvania	95.2	3.5	2.0	10.7	3.3	40.5	10.5	70.6

Table 1-3a—Stripper Well petroleum violation fund expenditures as of September 30, 1992 (continued)

State	Expenditures							Total ^a
	Total received	State Energy Conservation Program	Energy Extension Service	Weatherization Assistance Program	Institutional Conservation Program	Low-Income Home Energy Assistance Program	Other	
				(millions of dollars)				
Puerto Rico	21.7	0.2	0.1	0	0.9	0	0	1.2
Rhode Island	7.4	1.0	0.2	0.1	0	2.1	0.2	3.5
South Carolina	30.0	0.6	1.0	0	0.2	0	11.2	13.0
South Dakota	6.8	0.1	0.1	0	0	0	3.8	4.0
Tennessee	32.9	0	0	0	0	0	1.5	1.5
Texas	155.9	0	0	0	0.2	14.0	13.8	28.0
Trust Territories	0	0	0	0	0	0	0	0
Utah	13.6	0	0	0	0	0	3.0	3.0
Vermont	5.0	0.1	0	0	0	0.5	3.1	3.7
Virgin Islands	11.6	0	0	0	0	0	0.8	0.8
Virginia	58.5	0.7	0.2	0.4	1.0	5.6	15.3	23.2
Washington	29.7	0	0.6	0	0	0.5	10.3	11.4
West Virginia	10.8	0.3	0.3	1.5	0	0.7	5.8	8.7
Wisconsin	36.4	1.6	0	0	1.6	1.2	14.3	18.7
Wyoming	8.3	0	0	0	0	0.3	0.8	1.1
Total ^a	2,063.6	40.5	16.3	127.2	11.4	194.9	640.5	1,029.2

^aDue to rounding, total may not be exact.

components required electric service in areas without distribution line service. These components included bus shelter lighting, jogging and bikeway trail lighting, and street meridian sprinkler controls. Using an SECP grant of \$106,087 from the New Mexico Department of Energy, Minerals, and Natural Resources to supplement the \$2,063,000 city budget, as well as technical assistance from Sandia National Laboratories Design Assistance Center, the city installed photovoltaic-powered lighting systems at 20 locations and 15 solar-powered sprinkler control systems on street meridians. All photovoltaic systems were cost-effective on a first-cost basis (the cost of the solar electric systems was less than providing conventional power supplies). In addition, personnel costs for the system are lower, because minimal maintenance is required.

North Carolina

Using SECP funds, North Carolina was the first state in the Nation to implement statewide computerized routing

of public school buses. Using SECP funding, the state provided technical assistance to help local education agencies develop optimized school bus routes and school opening and closing schedules to minimize miles traveled and "dead time" between routes. To date, 89 local education agencies have optimized their scheduling and routing systems, and by 1994 all local agency systems will be fully operational. In 1991, the program saved 2.5 million gallons (9.5 million liters) of fuel. In addition, the program will save approximately \$810,000 annually will result from reduced repair costs, drivers' salaries, and tire replacement.

Pennsylvania

The Pennsylvania Energy and Environment Concept House, opened in April 1991, is used to teach public and private groups and other interested individuals about energy-efficient technologies for new and existing residential housing. This model house demonstrates various types

Table 1-3b—Stripper Well petroleum violation fund expenditures as of September 30, 1993 (million dollars)

State	Expenditures							Total ^a
	Total received	State Energy Conservation Program	Energy Extension Service	Weatherization Assistance Program	Institutional Conservation Program	Low-Income Home Energy Assistance Program	Other	
Alabama	30.4	0.1	0.6	0.0	0.5	2.3	19.2	22.7
Alaska	9.6	1.3	0.0	0.0	0.0	0.0	0.7	2.0
American Samoa	0.3	0.2	0.0	0.0	0.0	0.0	0	0.2
Arizona	23.4	0.1	0.0	0.0	0.0	0.7	8.7	9.5
Arkansas	25.4	0.0	0.0	2.9	0.0	2.1	18.3	23.3
California	193.1	31.0	0.0	0.0	0.0	7.1	94.3	132.4
Colorado	24.0	2.1	0.0	0.0	0.0	0.0	7.6	9.7
Connecticut	35.9	0.0	0.0	0.0	0.2	10.9	16.3	27.4
Delaware	10.7	0.0	0.0	1.7	0.0	0.2	6.0	7.9
District of Columbia ..	5.0	0.0	0.3	0.0	0.0	0.1	3.0	3.4
Florida	104.6	0.8	0.0	27.6	1.5	0.0	28.5	58.4
Georgia	49.5	3.4	3.2	0.0	0.0	7.9	12.5	27.0
Guam	3.4	1.1	0.0	0.0	0.0	0.0	0.0	1.1
Hawaii	16.2	3.0	0.5	0.0	0.0	0.0	1.1	4.6
Idaho	9.0	0.0	0.0	0.2	0.0	0.0	4.0	4.2
Illinois	99.0	0.0	0.0	0.0	0.3	17.1	44.7	62.1
Indiana	50.1	0.3	0.5	0.0	0.1	2.3	28.1	31.3
Iowa	28.6	0.0	0.0	0.0	0.0	0.0	22.5	22.5
Kansas	25.0	0.6	0.4	2.3	0.3	9.7	8.5	21.8
Kentucky	27.1	0.0	0.0	0.0	0.9	7.8	0.6	9.3
Louisiana	50.0	0.7	2.5	0.0	0.0	0.0	25.7	28.9
Maine	16.2	2.5	0.8	0.0	0.5	3.5	4.9	12.2
Maryland	40.6	2.3	0.3	11.4	0.0	14.0	3.8	31.8
Massachusetts	76.4	11.4	0.0	0.0	0.0	11.1	34.6	57.1
Michigan	72.2	2.4	0.0	19.1	0.0	17.6	25.0	64.1
Minnesota	39.1	0.0	0.0	15.8	0.0	0.0	13.9	29.7
Mississippi	28.8	1.5	0.0	1.9	0.1	1.0	12.3	16.8
Missouri	46.6	1.1	0.0	7.7	0.0	0.0	9.5	18.3
Montana	10.3	0.4	0.4	1.6	1.6	0.0	4.5	8.5
Nebraska	17.4	0.0	0.0	0.8	0.0	0.0	7.5	8.3
Nevada	7.9	0.3	0.1	0.4	0.1	2.5	4.5	7.9
New Hampshire	10.2	0.7	0.5	1.5	0.0	0.7	2.3	5.7
New Jersey	88.6	0.0	0.0	0.0	0.0	14.4	19.6	34.0
New Mexico	15.0	0.1	0.0	1.6	0.7	0.0	10.3	12.7
New York	181.7	5.6	0.0	21.9	0.4	0.0	65.2	93.1
North Carolina	57.1	0.0	0.0	2.4	0.0	0.0	19.9	22.3
North Dakota	8.2	0.1	0.0	0.0	0.0	1.7	3.0	4.8
Northern Marianas ...	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.1
Ohio	90.1	0.8	0.7	13.1	0.6	0.0	46.8	62.0
Oklahoma	25.3	0.0	0.0	0.0	0.0	0.6	17.7	18.3
Oregon	20.8	0.3	0.3	0.0	0.0	0.0	18.4	19.0
Pennsylvania	107.5	4.2	2.3	10.7	5.3	40.5	10.5	73.5
Puerto Rico	21.8	0.3	0.1	0.0	1.3	0.0	0.0	1.7
Rhode Island	8.4	0.5	0.2	0.1	0.0	3.5	0.2	4.5
South Carolina	28.4	0.8	1.1	0.0	0.3	0.0	12.6	14.8
South Dakota	7.5	0.1	0.1	0.0	0.0	0.1	4.3	4.6
Tennessee	38.7	0.0	0.0	0.0	0.0	2.1	11.9	14.0

Table 1-3b—Stripper Well petroleum violation fund expenditures as of September 30, 1993 (million dollars) (continued)

State	Expenditures							Total ^a
	Total received	State Energy Conservation Program	Energy Extension Service	Weatherization Assistance Program	Institutional Conservation Program	Low-Income Home Energy Assistance Program	Other	
Texas.....	170.3	0.0	0.0	1.0	0.7	16.0	77.4	95.1
Utah	14.9	0.0	0.0	0.0	0.0	0.0	3.7	3.7
Vermont	5.4	0.3	0.0	0.0	0.0	1.2	3.1	4.6
Virgin Islands	12.3	0.0	0.0	0.0	0.0	0.0	1.0	1.0
Virginia.....	60.4	1.6	0.6	0.4	1.2	5.6	15.3	24.7
Washington.....	33.3	0.5	1.1	0.0	0.0	1.3	18.8	21.7
West Virginia	11.6	0.4	0.4	2.1	0.0	0.7	5.8	9.4
Wisconsin	40.6	1.8	0.0	0.0	1.9	0.0	21.1	24.8
Wyoming	9.8	0.0	0.1	0.0	0.0	1.1	1.4	2.6
Total^a	2,243.9	84.8	17.1	148.2	18.5	207.4	861.1	1,337.1

Note: Total received includes interest reported to date.

^aBecause of rounding, totals may not be exact.

of insulation, vapor barriers, air infiltration barriers, and gaskets, and it illustrates good environmental techniques. The Energy and Environment Concept House is supported by local builders, a utility company, modular building manufacturers, the local school district vocational technical department, and local suppliers. Workshops are held to demonstrate how off-the-shelf technologies can be incorporated into new home design.

Rhode Island

The State of Rhode Island has implemented an energy consumption reduction program targeting 130 state facilities. The program has enabled the state to take advantage of utility rebates offered through demand-side management programs. One facility was able to reduce its electrical usage by 506,160 kilowatts during the first 6 months of operation by using variable-speed drives on its electric motors and installing energy-efficient lighting. This resulted in cost reductions of more than \$45,000 and a projected payback period of 0.78 year. Through implementation of this program, the state has been able to reduce its electrical usage by 2.5 megawatts, collect more than \$1.6 million in utility rebates, and reduce the annual cost of electrical use by \$0.8 million per year.

Washington

MotorMaster, a computer software program developed by the Washington State Energy Office with funding from DOE and the Bonneville Power Administration, compares the energy efficiency of more than 7,000 electric motor models sold in the United States. It includes information that allows engineers and technicians to easily identify motors that meet specific design requirements, such as full-, 1/2-, 3/4-, and 1-load efficiency; full-load revolutions per minute; voltage ratings; power factor; service factor; and frame size. An analysis feature of the MotorMaster program quickly calculates the cost of running a particular motor in a specific application and determines the simple payback of using a more efficient model. Menus and extensive help screens make MotorMaster easy to learn and use. It is available from the sponsors free of charge.

West Virginia

The West Virginia Fuel and Energy Office and the Governor's Office of Community and Industrial Development, in conjunction with the West Virginia University College of Engineering (Morgantown), developed the Energy Intern Program to bring together industry repre-

Table 1-4—State Energy Conservation Program grants

State	Grant		State	Grant	
	1992	1993		1992	1993
	(thousands of dollars)			(thousands of dollars)	
Alabama	187.8	173.6	Nebraska	108.8	100.5
Alaska	67.0	62.4	Nevada	88.0	82.8
American Samoa	51.1	47.2	New Hampshire	85.6	78.8
Arizona	150.3	140.2	New Jersey	371.7	341.6
Arkansas	172.0	159.0	New Mexico	100.6	93.5
California	801.1	746.8	New York	628.0	575.5
Colorado	154.1	144.0	North Carolina	250.1	232.0
Connecticut	166.4	152.5	North Dakota	70.1	64.5
Delaware	73.2	67.8	Northern Mariana Islands	51.1	47.2
District of Columbia	71.4	65.6	Ohio	466.5	429.8
Florida	359.8	336.5	Oklahoma	171.5	158.4
Georgia	241.8	225.5	Oregon	162.5	151.3
Guam	53.2	49.1	Palau	50.6	46.7
Hawaii	79.0	73.4	Pennsylvania	399.4	366.6
Idaho	80.5	75.0	Puerto Rico	127.9	116.9
Illinois	480.6	443.1	Rhode Island	90.2	83.0
Indiana	306.3	283.0	South Carolina	156.3	145.1
Iowa	161.4	148.7	South Dakota	69.6	64.4
Kansas	171.7	158.5	Tennessee	226.0	209.5
Kentucky	203.3	187.7	Texas	749.0	696.7
Louisiana	293.4	270.7	Utah	102.8	95.8
Maine	88.3	81.3	Vermont	72.3	66.7
Maryland	208.7	193.2	Virgin Islands	58.9	54.5
Massachusetts	234.8	214.4	Virginia	239.9	222.5
Michigan	379.7	350.0	Washington	169.0	158.7
Minnesota	227.7	210.6	West Virginia	156.1	144.0
Mississippi	138.3	127.6	Wisconsin	244.7	226.2
Missouri	215.2	198.2	Wyoming	74.3	68.7
Montana	77.4	71.7	Total	11,437.0	10,579.2

sentatives and senior-year engineering students from throughout the state to help industries improve productivity and to provide students with on-the-job experience. Students are placed in selected industrial establishments to assist in monitoring energy use and to make recommendations for reducing energy consumption. The typical internship lasts for a semester and earns the student 3 credit hours.

Energy Extension Service

The Energy Extension Service was a Federal-state partnership established by the National Energy Extension Service Act of 1977 to provide small-scale energy users with information and technical assistance tailored to their individual needs. Under this partnership, all states, the

District of Columbia, and U.S. territories received cost-shared grants to help individuals, small businesses, and local governments take practical steps toward energy efficiency. These activities were usually carried out in conjunction with SECP. EPACT repealed the Energy Extension Service, but its activities are authorized to continue under SECP.

Municipal Energy Management Applied Research Demonstrations

Thirty-one cities and counties conducted energy projects in 1992 through a cooperative agreement between DOE and the Urban Consortium Energy Task Force. These projects emphasized three core programs: (1) energy, environment, economic, and social development; (2) energy-efficient facilities; and (3) surface transportation.

Energy, Environment, Economic, and Social Development Projects

The Urban Consortium Energy Task Force's energy, environment, economic, and social development projects focused on activities that would carry forward previous years' work on energy management practices that promoted sustainable community development. The projects included a subtropical urban area demonstration in Dade County, Florida, that is part of the Urban Carbon Dioxide Reduction Project sponsored by the International Council for Local Environmental Initiatives; continuation of sustainable community implementation partnerships; a sustainable business development program; a case study on the municipal response to utility requests for demand-side management bids; a "green aisle" research program to promote business and consumer awareness of energy efficiency and environmentally benign products; the world's first 2-megawatt carbonate fuel cell power demonstration; a sustainable-building sourcebook targeting prospective homeowners and builders interested in "ecohome" construction; a marketing plan for a downtown district energy system in partnership with the local utility and district heating and cooling system operator; a case study of how a municipality participates in the design and implementation of statewide energy efficiency codes and standards; installation of new electric technologies to help industrial plants improve air quality; an educational center for sustainable urban development through the Earthways Home Project; marketing resource conservation to urban minority communities; and energy auditor training for high school students.

Energy-Efficient Facilities Projects

The consortium's energy-efficient facilities projects concentrated on public and private housing and city-owned or city-subsidized facilities. The projects included an energy fitness program targeting low-income and elderly households as part of a city-utility partnership to promote demand-side management measures; integration of IAQ management and energy rehabilitation and weatherization for low-income suburban homeowners; a residential energy conservation training curriculum for low-income residents; energy optimization of a city water distribution system; a management plan for chiller refrigerant maintenance and conversions to limit release of CFCs and HCFCs into the environment; establishment of a municipal energy services corporation; a solar cooling demonstration; and an energy management action plan based on the prior year's Sustainable Cities project.

Surface Transportation Projects

The consortium's surface transportation projects continued to emphasize alternative vehicular fuels and added an alternative to transportation: telecommuting. The projects included a public-private partnership to identify and help remove barriers to the implementation of large-scale-fleet natural-gas vehicles in ozone nonattainment areas; energy and economic analyses of transportation demand-side management strategies; city-operated natural-gas refueling sites and conversion services; a telecommuting plan for city employees; design of a multifuels service station; comparative analysis of methane- and compressed-natural-gas-fueled vehicles; demonstration of an alcohol injection system to reduce visible smoke emissions from diesel-fueled urban mass transit vehicles; and city budget strategies for meeting Clean Air Act mandates through low-emission vehicles, clean fuels, and diesel smoke and emission control inspection.

Weatherization Assistance Program

The primary purpose of DOE's Weatherization Assistance Program is to increase the energy efficiency of heating and cooling the residences of low-income families, particularly the elderly, persons with disabilities, and children, and thereby reduce their fuel costs. By reducing these costs, the program also enables low-income families to use larger portions of their incomes for other essential

needs. The program also reduces national energy consumption, especially of imported oil.

Weatherization grant awards are provided to all states, the District of Columbia, and, under certain circumstances, to Indian tribal organizations. The governor of each state applies, annually, for grant funds and distributes them to local agencies to weatherize homes. Certain Indian tribal organizations also administer Federal funds and provide weatherization services under the Weatherization Assistance Program.

Total appropriated funding for the program, from 1977 through 1993, has been approximately \$2.84 billion and is summarized in Table 1-5. DOE allocates funds to the states through a formula that reflects their relative needs for weatherization assistance (Table 1-6 summarizes 1992 allocations). The formula takes into account the number of low-income households, the percentage of total residential energy used for space heating and cooling, and the number of heating and cooling degree days in each state. A home is eligible for weatherization assistance if it is occupied by a family unit meeting one of several con-

ditions, including an income at or below 125 percent of the poverty level. The program is authorized by the Energy Conservation and Production Act of 1976, as amended by the National Energy Conservation Policy Act of 1978, the Energy Security Act of 1980, the Human Services Reauthorization Act of 1984, and the State Energy Efficiency Programs Improvement Act of 1990. Local service organizations (usually community action agencies) implement the program.

Services

Based on priorities established through energy audits conducted by local agencies, the Weatherization Assistance Program provides for the installation of such cost-effective weatherization measures as caulking and weatherstripping, wall and attic insulation, and heating system improvements. These measures also improve the thermal comfort level in homes and provide a healthier dwelling environment.

Training and Technical Assistance

The nature of weatherization services has evolved substantially since the Weatherization Assistance Program's beginning in 1977. Started as an emergency program, equipped with simple tools and materials such as plastic sheeting for storm windows, it has developed into a sophisticated energy conservation delivery system that uses blower doors, infrared scanners, computerized energy audits, and other state-of-the-art tools and techniques to maximize the energy efficiency of the dwellings it services.

In addition to grants for weatherization activities, DOE also provides funds for training and technical assistance. These efforts focus on two types of activities (1) the establishment of procurement procedures, reporting and record keeping requirements, and inventory controls and (2) development of the specific weatherization skills needed at the local level, such as blower door and infrared scanner operation, insulating walls, and conducting energy audits.

As part of the training and technical assistance effort during 1992, the program developed the National Energy Audit (NEAT) as a model for states; by adapting it to their own specific circumstances, they can improve program performance. States that move aggressively to adopt improved energy audit techniques also gain increased flexibility in program operations compared with previous statutory and regulatory requirements.

**Table 1-5—Weatherization Assistance Program
total funds, 1977-93**

Year	Appropriation
	(millions of dollars)
1977	27
1978	65
1979	199
1980	199
1981	175
1982	144
1983	245
1984	190
1985	191
1986	182
1987	161
1988	161
1989	161
1990	162
1991	198
1992	190
1993	185
Total	2,835

Table 1-6—Weatherization Assistance Program formula grant allocations as of January 9, 1992

State	Total grant	State	Total grant
	(millions of dollars)		(millions of dollars)
Alabama	1.8	Montana	2.1
Alaska	1.6	Nebraska	2.4
Arizona	0.7	Nevada	0.5
Arkansas	1.6	New Hampshire	1.6
California	4.8	New Jersey	5.2
Colorado	4.2	New Mexico	1.5
Connecticut	2.6	New York	19.1
Delaware	0.7	North Carolina	3.2
District of Columbia	0.7	North Dakota	2.3
Florida	0.8	Ohio	11.0
Georgia	2.0	Oklahoma	2.0
Hawaii	0.2	Oregon	2.5
Idaho	1.8	Pennsylvania	13.0
Illinois	11.5	Rhode Island	1.2
Indiana	5.5	South Carolina	1.2
Iowa	4.5	South Dakota	2.0
Kansas	2.1	Tennessee	3.5
Kentucky	3.7	Texas	2.7
Louisiana	0.9	Utah	1.8
Maine	3.1	Vermont	1.3
Maryland	2.5	Virginia	3.3
Massachusetts	6.4	Washington	3.9
Michigan	12.6	West Virginia	2.6
Minnesota	9.3	Wisconsin	7.4
Mississippi	1.2	Wyoming	0.9
Missouri	5.0	Total^a	188.9

^a Due to rounding, total may not be exact.

The Weatherization Assistance Program recently issued a final rule (10 CFR 440, published in the March 4, 1993, *Federal Register*, p. 12514 et seq.) incorporating the provisions of Public Law 101-440, the State Energy Efficiency Programs Improvement Act of 1990. States began implementing these new provisions in April 1993. The program is developing training sessions with the states to enhance program performance.

Key Accomplishments

Since the Weatherization Assistance Program began, DOE's network of 1,100 local agencies has retrofitted more than 4 million dwellings. In recent years, the network has weatherized approximately 250,000 homes per year with DOE and "leveraged" funds. In 1990, DOE commissioned the Oak Ridge National Laboratory to conduct a national

evaluation of this program. The results of the National Weatherization Evaluation, which focused on the 198,000 single-family and small multifamily dwellings that were served by the 1989 program, were released in 1993.

The evaluation found that dwellings weatherized in 1989 saved an average of 17.6 million Btu (MBtu; 18.6 million kilojoules) during the first year after weatherization, representing an 18.2-percent reduction in the energy used for space heating, and a 13.5-percent decrease in total energy use. For all 198,000 dwellings, this translates into an annual savings of 3.5 MBtu (3.7 million kilojoules), or the equivalent of approximately 601,000 barrels of oil (82,000 metric tons). Over the 20-year lifetime of the weatherization measures, the energy savings from program year 1989 expenditures amount to 12 million barrels of oil (1.6 million metric tons).

The evaluation also found the Weatherization Assistance Program to be a cost-effective government investment. Total weatherization costs (including materials, labor, overhead, and management) averaged \$1,550 per dwelling. The net present value of energy saved per dwelling is \$1,690 (in 1989 dollars). This results in a benefit-cost ratio of 1.09; and when values are included for some of the program's various non-energy benefits, such as the creation of jobs and the rehabilitation of homes, the benefit-cost ratio increases to 1.72.

New Directions

The Weatherization Assistance Program will continue to emphasize leveraging activities at the state and local levels to increase the number of clients that it can serve. By encouraging program operators to address home heating and cooling systems, the new regulation (see "Training and Technical Assistance," above) provides an incentive for utilities across the country to participate as active partners with local agencies in maximizing the weatherization dollars being spent. Many utilities have already entered into this partnership. The increased emphasis on sophisticated audits has given state and local agencies a professional, polished image as deliverers of quality energy efficiency services.

The new weatherization regulations provide for DOE funding to address health and safety issues for the first time. Likewise, the new rule contains specific provisions regarding the rights of tenants who receive weatherization services. In sum, the new regulation will provide states with additional flexibility to address the needs of their low-income citizens. DOE is encouraging states to be as creative as they can in developing new approaches to their

programs and to share their ideas and innovations with others.

Institutional Conservation Programs

"Partners With the Nation's Schools and Hospitals for Energy Efficiency and Savings," is the new slogan adopted in 1992 by the Institutional Conservation Programs (ICP). For ICP, 1992 and 1993 marked a period of new direction, new birth, and change. The new slogan best defines the new look for ICP, for it both acknowledges the ICP tradition of promoting energy efficiency in the institutional building community and establishes the new expanded role of ICP for the ensuing years.

The publication of the new program rule on February 19, 1993, was a significant step in this new direction. The revised rule incorporates the amendments authorized by the State Energy Efficiency Programs Improvement Act of 1990 (Public Law 101-440), as well as numerous other revisions to improve or clarify program operations. The major changes in the rule include a change in the building construction eligibility date from April 20, 1977, to May 1, 1989; adding flexibility to the energy audit and technical assistance program procedures; broadening the eligibility of certain types of buildings and energy conservation measures; allowing states a number of options regarding ICP operations; raising the state administrative grant base amount for these grants and deleting the matching requirements; new flexibility regarding title to equipment where a grant recipient's non-Federal matching funds are borrowed; and new grants that allow states to fund technical assistance, program assistance, and marketing initiatives from their appropriated allocations if the states can provide non-Federal funding for energy conservation measures.

ICP conducted training in conjunction with the revised rule in two phases. In the first phase, ICP Headquarters and support office staff received training at the semiannual meeting held in April 1993; in the second phase, the state ICP staff received training at the ICP National Conference held May 18 to 27, 1993. For the first time, the training was provided on computer disk, and each state received a copy.

While establishing a new direction, ICP will continue to administer the components of a traditional grant program, which will be enhanced somewhat in light of the revised rule. These enhancements include the new grants

for technical assistance, program assistance, and marketing activities. Through 14 grant cycles, starting in 1979, ICP has developed a definite pattern of success in energy conservation in school and hospital buildings. To date, ICP has provided \$860 million in Federal assistance under 25,357 grants for energy-efficiency improvements in 67,000 buildings; cumulative savings are estimated at \$4.6 billion.

ICP awards grants competitively on a fifty-fifty matching basis directly to eligible schools and hospitals. These awards result in grants to perform technical assistance analyses or energy conservation measures. Technical assistance analysis is a detailed engineering analysis of an entire building structure. The purpose of this engineering analysis is to provide institutional management with a comprehensive planning document for building energy efficiency. Such measures are the design, acquisition, and installation of major energy-saving measures as identified in the technical assistance analysis. Such measures can involve projects as basic as window replacements and interior lighting conversions up to measures as extensive as the installation of energy management systems and major boiler replacements.

ICP receives an annual appropriation from Congress. This appropriation, combined with carryover funds from the prior year, forms the total funding amount for the current grant cycle. This total funding amount, once calculated through a formula, results in individual state allocations. The 1993, cycle 15 national allocation is \$39.3 million (Table 1-7). This funding is supplemented from other sources, including oil overcharge monies, and is matched, on a fifty-fifty basis, by each recipient institution, resulting in program outlays of more than \$168 million.

During 1992, ICP initiated or continued a series of outreach projects, including the following:

1. The Reduce Swimming Pool Energy Costs (RSPEC!) partnership program encourages both the public sector and private industry to support the use of a solar hybrid heating system and a pool cover to substantially reduce the energy costs of operating commercial and municipal U.S. swimming facilities. ICP implemented a full-scale marketing effort regarding RSPEC!, which included an information package and a videotape. ICP is participating in the 1996 Olympic Task Force as an active means to showcase the RSPEC! technologies.
2. The Polish American Children's Hospital in Kraków, Poland, is a project site where the transfer of U.S.

technology will improve building energy efficiency. ICP supported a survey of the hospital's thermal energy supply and demand system, which in turn identified four significant low-cost measures that will reduce energy requirements at the hospital. Discussions are under way to explore the possibility of private-sector funding for these initiatives.

3. ICP has funded a joint public- and private-sector venture to determine the energy efficiency needs of Hungary's institutional building sector. Audits were conducted on three "test case" buildings: a primary school, a city office building, and a medical center. Research on alternative methods for financing energy retrofits to the test-case buildings has also been accomplished, including outlining the availability of international and domestic sources of financing for these projects.
4. Along with the Office of National Programs, ICP cosponsored the Waste Management Educational Project. "Wasteworld" is a computer simulation that allows students to manage their own community's municipal solid wastes. This project will initially target waste management computer modules in the curricula of grades 5 and 6.
5. ICP distributed the software package and manual for the Retrofit Energy Savings Estimation Model. ICP managers can use the model to verify post-retrofit energy savings in school, hospital, and college buildings.
6. As an additional outreach approach, ICP continues to use the portable display, the videotape "ICP + You = Savings," *The ICP Observer*, hallway visual presentations, and the new ICP banner as tools for information dissemination. During 1992 and 1993, ICP Headquarters, support office, and state personnel used these tools in seven major energy-related conferences and expositions, held in Alabama, California, Colorado, Georgia, Illinois, Minnesota, and Washington, D.C.

A highlight of 1992 was the National Energy Program Managers Conference held in St. Paul, Minnesota. The theme of the national conference was "Taking Charge of Our Future—New Approaches and Emerging Roles." ICP cosponsored this event with SECP. "ICP in Transition: Initiatives-Challenges-Partnerships" was the theme for the ICP National Conference held May 24 to 27, 1993, in Point Clear, Alabama. More than 125 individuals, representing ICP Headquarters, support office, and state personnel, attended. This conference was devoted exclusively to ICP

Table 1-7—Institutional Conservation Program state allocations

State	Total funds		State	Total funds	
	1992	1993		1992	1993
	(millions of dollars)			(millions of dollars)	
Alabama	0.5	0.5	Montana	0.2	0.3
Alaska	0.2	0.3	Nebraska	0.3	0.4
American Samoa	0.1	0.1	Nevada	0.3	0.3
Arizona	0.5	0.5	New Hampshire	0.3	0.3
Arkansas	0.3	0.4	New Jersey	1.0	1.2
California	2.4	2.3	New Mexico	0.3	0.3
Colorado	0.6	0.7	New York	2.3	2.8
Connecticut	0.5	0.6	North Carolina	0.7	0.8
Delaware	0.2	0.2	North Dakota	0.2	0.3
District of Columbia	0.2	0.2	Northern Mariana Islands	0.1	0.1
Florida	1.3	1.4	Ohio	1.4	1.7
Georgia	0.7	0.9	Oklahoma	0.5	0.5
Guam	0.1	0.1	Oregon	0.4	0.5
Hawaii	0.2	0.2	Pennsylvania	1.6	1.9
Idaho	0.3	0.3	Puerto Rico	0.5	0.5
Illinois	1.7	2.0	Rhode Island	0.2	0.3
Indiana	0.8	1.0	South Carolina	0.4	0.4
Iowa	0.5	0.6	South Dakota	0.2	0.2
Kansas	0.4	0.5	Tennessee	0.6	0.7
Kentucky	0.5	0.6	Texas	1.8	2.0
Louisiana	0.5	0.5	Utah	0.4	0.4
Maine	0.3	0.4	Vermont	0.2	0.2
Maryland	0.6	0.7	Virgin Islands	0.1	0.1
Massachusetts	0.9	1.1	Virginia	0.7	0.8
Michigan	1.4	1.7	Washington	0.7	0.7
Minnesota	0.9	1.0	West Virginia	0.3	0.4
Mississippi	0.3	0.4	Wisconsin	0.9	1.0
Missouri	0.7	0.8	Wyoming	0.2	0.2
			Total^a	34.4	39.3

^aDue to rounding, total may not be exact.

issues; the primary focuses were training and discussions regarding implementation of the final revised ICP rule. Attendees discussed these rule-related issues during both an overview session and regional breakout sessions. Other key conference sessions included "Marketing ICP," "The ICP Way to Life-Cycle Costing," "Third Party Financing," and "Engineering for Non-Engineers."

Energy-Related Inventions Program

Established in 1974 under the Federal Nonnuclear Energy Research and Development Act (Public Law 93-577), the Energy-Related Inventions Program (ERIP) assists in the

development of nonnuclear inventions that are technologically and commercially feasible and that can improve the efficiency of energy supply and use. Although the program can, and does, offer evaluation services and grants to universities and large entities, it must pay "particular attention to individual inventors and small companies" (section 14, Public Law 93-577). The goal of the program is to help inventors who, because of inexperience or lack of funds, are unable to advance their inventions to a stage that attracts investors or licensees. ERIP grants support prototype development, testing, applied technical research, and other precommercialization activities.

ERIP has awarded more than \$32 million in grants to date; the average grant in recent years has been about \$83,000. During 1992, DOE issued almost \$2.6 million in grants to 28 inventors. According to the 1993 biannual evaluation report from Oak Ridge National Laboratory, more than 108 inventions supported by ERIP had entered the marketplace by the end of 1990—accounting cumulatively for more than \$534 million in sales. The almost 20:1 ratio of cumulative sales (\$1.534 billion) to grants (\$132 million) in that report is an indicator of how Federal investment in these technologies at a critical stage of their development can pay off in economic growth. About 25 percent of all ERIP inventions have had sales in 1990, the year of the last evaluation. In addition, the development and sales of ERIP-supported technologies supported as many as 750 jobs. One important finding of the report is that because of Federal income taxes paid by individuals employed by these companies, approximately \$3.2 million was returned to the U.S. Treasury in 1990, a figure that exceeds the amount of grants awarded that year. ERIP provides positive financial and economic returns to the United States in many ways.

ERIP accepts submissions of inventions at any stage of technical development, and the inventors' sophistication varies considerably. There is no cost to submit a request for a confidential technical evaluation of an invention. The Federal Nonnuclear Research and Development Act requires the National Institute of Standards and Technology (NIST) to conduct preliminary evaluations and rate inventions for technical feasibility, energy impact, and commercial potential. The Institute then forwards the most promising inventions to DOE for consideration of financial and technical assistance. Since ERIP began in 1975, more than 30,000 inventions have been submitted to NIST for evaluation, and the Institute has recommended almost 600 of these submissions for DOE support. Approximately 80 percent of these have received ERIP grants. Nearly all of them have received some type of nonfinancial assis-

tance from the program, such as commercialization planning and referrals to state and local organizations.

In 1992, ERIP conducted four quarterly Commercialization Planning Workshops for prospective grantees to improve their understanding of product and business development. Two of these workshops were conducted in conjunction with the Texas Department of Commerce's Office of Advanced Technology, which uses some of its petroleum violation escrow funding to provide loans for energy-related innovations. The workshop therefore served as one of the many loan evaluation factors. To date, there have been two Commercialization Planning Workshops held, including one cosponsored by California State University's Center for New Venture Alliance at Hayward. This workshop had participants from the university, the National Industrial Competitiveness through Energy, Economics, and Environment (NICE³) program, and the Idaho National Engineering Laboratory.

ERIP also held six National Innovation Workshops around the country to encourage innovation and introduce the program to inventors and small businesses. These workshops were jointly sponsored by area businesses, small business development centers, and universities.

Innovative Concepts Program

DOE established the Innovative Concepts Program (InnCon) in 1983 as a means of providing support for radically different approaches to specific problems. InnCon provides seed money to individuals, businesses, and universities with concepts for energy-conserving techniques in specified areas. The program solicits these concepts through formal requests for proposals on a selected topic and typically makes up to 15 awards of approximately \$20,000 in each project cycle to conduct preliminary technical and economic evaluation and move each concept a step forward. After concept development is completed, InnCon publicizes the concept at a technology fair to attract potential follow-on sponsors to advance the new technology.

Five InnCon project cycles have been completed since 1983. InnCon has awarded a total of 55 subcontracts and grants in the topic areas of building materials, industrial processes, industrial separations, building retrofit, and waste stream prevention technologies. In the sixth project cycle, again focusing on waste stream prevention, minimization, and use, InnCon made another 15 awards of up to \$20,000. The DOE Offices of Environmental Restoration and Waste Management, Industrial Technologies,

Fossil Energy, and Technology Utilization provided cost sharing in an amount almost equal to the program appropriation. A technology transfer fair cosponsored by these organizations, the Texas Department of Commerce's Office of Advanced Technology, the Licensing Executives Society, and the National Technology Transfer Center was held in April 1993.

Of the 55 projects supported by InnCon, 25 have received an aggregate of more than \$12.5 million in follow-on funding from a Federal investment of slightly more than \$900,000. A project on ammoniated complex compounds for heat pumps has leveraged its \$15,000 InnCon support into a new business to develop the technology; the company, Rocky Research, has received more than \$7 million in funding and has been awarded 10 patents, with 12 more pending. The company has also licensed the technology to another company and has four more licenses pending.

Center for the Analysis and Dissemination of Demonstrated Energy Technologies

In 1988, the United States joined with nine other nations (Denmark, Finland, Italy, The Netherlands, New Zealand, Norway, Sweden, Switzerland, and The United Kingdom) to create the Center for the Analysis and Dissemination of Demonstrated Energy Technologies (CADET), an International Energy Agency center responsible for collecting and disseminating information on demonstrated energy-efficient technologies. In 1990, Australia and Canada joined CADET, expanding membership to 12. Japan joined in 1991, and Belgium joined in early 1993. The center focuses on demonstration projects of full-scale applications of new technologies under real-life, normal working conditions.

CADET distributes the results among its member countries. In the United States, private-sector participation has been generated through the creation of a CADET National Team. Members of U.S. industry, utilities, universities, national laboratories, and industry research institutes as well as other interested parties nominate demonstration projects for CADET dissemination. CADET achieves its objectives through workshops and, more importantly, through the publication and dissemination of brochures, a data base of demonstrated energy technologies, analytic studies, and quarterly newsletters.

In 1992 and 1993, CADET continued to distribute brochures on new demonstrated technologies developed

by member countries. The center has published more than 140 brochures, including 20 contributed by the United States. It published one new analysis report, *Energy Efficient Retrofitting of Office Buildings*. CADET expanded its data base of demonstrated energy technologies to 1,633 records, 402 of which were contributed by the United States. Information in the data base covers the contents of demonstration projects, energy consumption and savings, experiences gained from the projects, economics, investment costs, operational costs, energy cost savings and payback periods, and document references and addresses.

Joint Deployment Efforts

For many years, the R&D program offices of the Office of the Assistant Secretary for Energy Efficiency and Renewable Energy (EERE) have sponsored research at the national laboratories and elsewhere on new renewable energy and energy efficiency technologies. These technology efforts are focused on the energy end-use sectors: buildings, industry, transportation, and utilities. In recent years, EERE has made a concerted effort to combine the resources of these research programs with those of its outreach arm, the Office of Technical and Financial Assistance, and its 10 regional support offices. Traditionally, the Office of Technical and Financial Assistance and the support offices have administered the DOE state grant programs: the Weatherization Assistance Program, the Institutional Conservation Program and the State Energy Conservation Program. In recent years, the mission of the Office of Technical and Financial Assistance has been broadened to include the deployment of renewable energy and energy efficiency technologies developed by EERE's research, development, and demonstration offices, giving those offices greater access to regional, state, and local networks and resources. To give focus to this expanded mission and to make the best use of its resources, the Office of Technical and Financial Assistance has identified seven sets of technologies on which it will concentrate: alternative motor fuels, energy-efficient electric motor systems, integrated resource planning, renewable electric generation, building efficiency, integrated waste management, and solar industrial thermal energy.

In collaboration with the EERE research, development, and demonstration offices, the Office of Technical and Financial Assistance has launched a planning process to develop multiyear plans guiding the development and implementation of joint deployment activities for each of the seven technologies. The plans select priority activi-

ties, define roles, and identify resources. This planning process helps not only to ensure that the Office of Technical and Financial Assistance effectively deploys proven renewable energy and energy efficiency technologies, but also encourages emerging technologies that can conserve and supplement energy supplies. Approximately 40 projects are being implemented in 1993, at a total cost of roughly \$10 million, which is cost-shared between the Office of Technical and Financial Assistance; the 4 EERE research, development, and demonstration offices; and funding sources outside DOE.

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CHAPTER 2

RENEWABLE ENERGY

INTRODUCTION

One of the primary goals of the Office of Energy Efficiency and Renewable Energy is to enable the Nation to meet its growing energy needs at the least cost to society and, as much as possible, to do so through the combined contributions of improved efficiency and renewable energy. To achieve this goal, the office is pursuing a two-fold strategy.

First, the office is advancing technology through research, development, and performance verification, in close collaboration with industrial partners wherever practical. Second, the office is working to reduce barriers to market competition with technology and market deployment activities. It encourages the increased use of energy-efficiency and renewable energy technologies through information dissemination, joint ventures, Federal procurement (to prime the market for new products), and regulatory and legislative action at the Federal and state levels.

To gain acceptance of renewable energy technologies in the marketplace, it is absolutely essential that the office's programs meet the needs of industry. The number of private-sector partners willing to cost-share key research projects is evidence that the private sector has a legitimate interest in these technologies. The Solar Industrial and photovoltaics programs are examples of such public-private partnerships.

The Solar Industrial Program works cooperatively with suppliers and potential users to commercialize solar-based processes. During 1993, DOE developed a comprehensive 5-year plan in collaboration with industry and other key players to map out a strategy for developing and commercializing solar thermal electric technologies by the end

of the decade. This would be done primarily through joint ventures in which the Department and industry would share the costs equally. Five of the solar power stations supplying electricity to the utility grid in southern California have joined with DOE in a \$7 million, fifty-fifty cost-shared program to reduce the operation and maintenance costs of these plants. The lessons learned in this project will be applied to the 100- to 200-megawatt commercial power-tower plants that are to be built by the year 2000.

In 1991, DOE established a 5-year, \$110 million program to identify and address the most critical manufacturing needs for photovoltaics. DOE issued contracts to 22 U.S. photovoltaics companies in a cost-shared agreement to identify specific improvements in their production processes. All phase-one contracts were completed in 1992. In phase two of the project, seven of these companies, under cost-share contracts, are currently working to solve the process-specific problems identified in phase one.

The Nation continues to consume large amounts of petroleum in transportation. Strong dependence on imported oil risks the Nation's security; and the Nation's health is at risk from polluting the air with the byproducts of fuel combustion. In an effort to clean the air and reduce dependence on foreign oil, the Department sponsored a voluntary Federal program, Clean Cities, which is designed to accelerate and expand the use of alternative-fuel vehicles in urban communities and provide refueling and maintenance facilities for their operation. Clean Cities demonstration programs are under way in Atlanta, the District of Columbia, and Philadelphia. By 1996, Clean Cities will result in the acquisition and operation of 250,000 additional alternative-fuel vehicles and 1,000 additional refueling stations throughout the country.

The Department's Biofuels Program began strategic planning in 1993 to more closely align its goals and objectives with those of industry. The primary goal of the Biofuels Program is to provide the technology base and infrastructure required to introduce, by 2000, domestically produced, economically viable renewable transportation fuels. These fuels would be competitive with petroleum-based fuel without the need for subsidies. Beyond 2000, the Department projects that biomass-derived fuels and blending components will be substantially cheaper than petroleum-based fuel and component alternatives. During the past 2 years, the program has developed two cooperative research and development agreements, one multi-industry consortium, and three industry demonstration projects representing a wide range of industry participants. DOE expects this process to expand in 1994–1995, both in conversion technology and in feedstock development.

The Office of Technical and Financial Assistance administers the Committee on Renewable Energy Commerce and Trade (CORECT). This working group of 14 Federal agencies facilitates the export of U.S. renewable energy products and services. Working closely with private industry, CORECT agencies have focused their efforts on developing new overseas markets, helping overseas customers solve problems of finance, and educating and training potential foreign customers in the use of U.S. renewable energy equipment and services. During 1992 and 1993, CORECT concentrated its market development activities on Latin America and the Caribbean, areas with much potential for renewable energy. CORECT also collaborated with industry in a new initiative, Renewable Energy for African Development.

American industry recognizes the importance of renewable energy programs. Increasingly, industries are forming joint partnerships with the Department to develop renewable energy technologies and programs that will enhance their interests and near-term marketplace opportunities.

UTILITY TECHNOLOGIES

Two program offices manage the renewable energy research and development (R&D) activities of the Office of Utility Technologies: the Office of Renewable Energy Conversion, which has responsibility for geothermal, hydropower, wind, and ocean energy activities, and the Office of Solar Energy Conversion, which oversees the photovoltaic (PV), solar thermal, and biomass electric

energy activities. These offices design their individual projects to take advantage of both "technology push" and "market pull" to promote the use of the Nation's considerable renewable energy resources. "Technology push" refers to R&D advances that bring technologies more quickly to commercial maturity; "market pull" refers to activities that stimulate market demand and address institutional and economic barriers to the acceptance and widespread use of renewable energy technologies.

Both program offices work closely with private industry to shape their programs by identifying key technological and nontechnological constraints on deployment of program technologies and through periodic industry review of program activities. For example, private-sector partners play an important role in structuring the Department's Wind Energy Program. Because of wind industry input, this program gives priority to resolving critical reliability and performance issues (by examining wind-airfoil interactions and wind turbine structural dynamics) and to developing next-generation, utility-scale advanced wind turbines, both of which are critical items in the process of building U.S. industry's competitiveness. DOE is also collaborating with the electric utility sector to demonstrate a 10-megawatt molten-salt solar thermal central receiver facility that should serve as a precursor to commercialization of the technology in the latter part of this decade. The private sector is also deeply involved in DOE's geothermal R&D program to increase resource availability and cost-effectiveness. The geothermal industry, through consortia and other mechanisms, supports activities that emphasize advanced exploration technology and reduced drilling and conversion costs. This close working relationship with industry also characterizes the Photovoltaics Program (PV Program). Through such efforts as Photovoltaics for Utility-Scale Applications (PVUSA), a project aimed at giving electric utility personnel hands-on experience with large-scale PV systems, and the Photovoltaic Manufacturing Technology (PVMaT) Project, a project aimed at reducing manufacturing costs for PV systems, the Department is making every effort to expedite PV technology's transfer to the private sector. In all these efforts, there is considerable cost sharing by DOE's private-sector partners and strong emphasis on building U.S. industrial competitiveness and U.S. technological leadership in the marketplace. In the area of hydropower, the Department is focusing on defining environmental mitigation methods and regulatory issues that can inhibit further hydropower development and relicensing of existing facilities.

In 1990, DOE anticipated that electricity demand would grow at an average annual rate of 2.1 percent until 2030.

In addition, the Department projected that the Nation would need 200 gigawatts of additional capacity from both utility and nonutility generators by the year 2010, a need that the Nation most likely would have to meet with a combination of baseload coal plants, gas-fired combined-cycle or combustion turbine plants, renewable energy systems, and enhanced conservation and load management programs. This growth in demand is providing opportunities for renewable energy technologies to compete with other technologies for peak-, intermediate-, and baseload power generation. Some regions of the United States are already operating on low reserve margins (the unused capabilities of power systems during peakload). Without intensive conservation efforts, these low reserve margins will further increase the need for electrical capacity over the next two decades. Some utilities are reluctant to build additional facilities because of financial and regulatory uncertainties and inhibitions on the use of new technologies. DOE expects the recent trend toward independent power production to continue, and the Energy Policy Act of 1992 (Public Law 102-486) includes regulatory and legislative proposals to enhance competition in bulk power generation.

Increasing public and regulatory concern for the environmental impacts of energy production continues to challenge utilities to balance environmental and economic factors in meeting needs for new generating capacity. Of particular concern are powerplant emissions of sulfur dioxide and nitrogen oxides, which are acid rain precursors, and uncertainty about the long-term climatic impacts of carbon dioxide, a greenhouse gas. Renewable energy sources have the potential to help meet both energy and environmental objectives, because the environmental impacts of renewable energy technologies are often significantly less than those of conventional technologies. The availability of renewable energy technologies expands the options that utilities may consider as they strive to meet their customers' energy service needs. By enhancing utilities' energy supply options, the Office of Utility Technologies is helping them to minimize the risks that they face in meeting the Nation's future need for an efficient, flexible, reliable, and environmentally acceptable electricity supply system in a complex economic and regulatory environment.

Hydroelectric Systems

In 1992, hydroelectric plants (conventional and pumped storage) provided 91 gigawatts of electric generating ca-

capacity—approximately 12 percent of the Nation's total capacity.

Environmental and Institutional Issues

In response to barriers to relicensing and to further development of the hydropower industry, the DOE hydropower program has focused on mitigation of environmental concerns. In January 1992, the program issued the first volume of an environmental mitigation study documenting current practices for fish passage, instream flow, and dissolved oxygen.

Resource Assessment

In cooperation with the Federal Energy Regulatory Commission and the power marketing administrations, DOE has established uniform criteria to describe hydropower resources and development potential, as well as hydropower evaluation software to guide the updating and revision of state and regional data bases. The information developed is valuable both as a basis for future policy determinations and as an aid in estimating and characterizing developable hydropower resources. In 1992, DOE began applying the uniform criteria and software to 12 states; these activities were coordinated by the Southwest Power Administration and the DOE Denver Support Office.

Biomass Systems

Electricity produced by biomass in the United States has grown from 0.2 gigawatts in the early 1980s to nearly 8.0 gigawatts today. In addition to representing a renewable form of power production, biomass powerplants can provide benefits. For example, biomass releases negligible sulfur dioxide and nitrogen oxide emissions. In addition, crops grown for biomass generation remove as much carbon from the atmosphere as is released when they are burned to generate electricity. These features mean that closed-loop biomass systems are net-zero emitters of carbon dioxide. Biomass combustion also contributes to national energy security by helping reduce U.S. dependence on imported oil.

The current method for converting biomass to electricity is by producing steam in a biomass-fired boiler to drive Rankine steam turbines. However, biomass converted to low- or medium-heat-content gas could feed steam-injected gas turbines, which are 1° times more efficient than simple Rankine steam turbines. Industry is also interested in biomass gasifier systems because they are compatible with

gas turbine technology derived from the aerospace industry. Economic studies by universities and industry indicate that there is significant potential for small wood gasification systems in international and domestic markets.

In 1990, the Office of Solar Energy Conversion began evaluation studies and small-scale gasification experiments to address the major research issues facing electric power production from biomass. In 1991, the office selected the Pacific International Center for High Technology Research as an industrial partner for a joint venture to build a 100-ton-per-day (90-metric-ton-per-day) gasifier (sufficient for a 5-megawatt turbine).

In 1992, DOE completed negotiations with Power Generation, Inc., of Forth Worth, Texas, on a fifty-fifty cost-shared contract as part of an attempt to develop a commercial, direct-fired, sawdust-fueled steam generation system. The Department awarded a subcontract to Manufacturing and Technology Conversion International, Inc., of Columbia, Maryland, for operation of a 25-ton-per-day (23-metric-ton-per-day) indirectly heated gasifier on high-alkali agricultural wastes. Also in 1992, the Department established six cost-shared partnerships, through a subcontract with Miles Consulting Engineers (Portland, Oregon) for the investigation and eventual solution of alkali deposition problems occurring in biomass power generation systems; the Electric Power Research Institute, the Bureau of Mines, and the Western Regional Biomass Energy Program will support the study.

During 1993, DOE developed a comprehensive 5-year plan in collaboration with industry and other key players. The 5-year plan maps out a strategy for developing and commercializing various biomass power technologies by the end of this decade, primarily through cost-shared joint ventures between the Department and industry. The Department selected the Westinghouse Electric Corporation of Orlando, Florida, to develop a hot-gas cleanup system to be tested on a 100-ton-per-day (90-metric-ton-per-day) gasifier in 1994. This system is currently being constructed at the Institute of Gas Technologies' pilot gasifier facility in Chicago.

Solar Electric Technology: Photovoltaics

During 1992, years of work by the PV Program and industry to demonstrate PV technology and educate users began to pay increasing dividends in terms of new markets and overall market growth. R&D results under the

program also continued to make steady progress in improving the performance and durability of collectors and systems and in improving the basic core elements, PV materials.

In manufacturing technology development, the PV Program continued Phase 2A Photovoltaic Manufacturing Technology (PVMaT) contracts with seven PV module manufacturing companies to improve specific production line processes, and Phase 3A contracts with two companies to improve generic problems. DOE initiated PVMaT in 1991 to assist the PV industry in producing, through the use of advanced manufacturing technologies, the improved, lower cost module products the industry needs to retain a leadership position in the world market.

Photovoltaics Research and Development

In 1992 and 1993, each of DOE's core PV R&D activities made continued, significant progress that will lead to production of more efficient and reliable PV products by the PV industry in the next few years.

Fundamental Research in Materials and Devices

In 1992, fundamental materials research performed in DOE laboratories, in universities, and in industry continued to increase the conversion efficiencies for several PV materials. A workshop held in July 1992 with representatives from DOE laboratories, universities, and industry identified new fundamental research opportunities in PV materials and devices. Work also continued in solid-state theory research as a means of helping to develop a fundamental understanding of solar cell performance by modeling the electronic structure of prototype materials. This theoretical work will help guide experiments to develop higher efficiency devices.

Advanced Thin-Film Materials and Devices

In 1992 and 1993, the PV Program continued to support the Polycrystalline Thin-Films Initiative, which has continued to produce outstanding results. By the end of 1992, the National Renewable Energy Laboratory (NREL) had awarded \$5 million in industry (cost-shared) and university contracts under this initiative, with three of the industrial participants selected for utility-scale deployments in the PVUSA project. Also in 1992, a world-record efficiency of 15.8 percent was validated for a cadmium telluride, and a 4-square-foot (0.4-square-meter) copper indium diselenide module achieved an efficiency of 9.7 percent.

These results have positioned thin-film-based modules to be competitive in the near future with conventional crystalline silicon modules.

High Efficiency Materials and Devices

In 1992 and 1993, DOE continued a number of studies in high-efficiency crystalline semiconductor materials, including silicon, gallium arsenide, and related compounds. This research indicated that efficiency goals of 20 percent for flat-plate modules and 25 percent for concentrator modules can be met. Of significance in 1992 was the cooperation achieved between Texas Instruments, Inc., of Dallas, Texas, and Sandia National Laboratories to improve the performance of Texas Instruments' spherulic silicon material. DOE's assistance could improve the material's spectral response, and thus efficiency, at a fairly low cost.

Photovoltaic Manufacturing Technology and Development

The PVMaT Project is a significant step forward in creating industry-DOE partnerships. During the 5-year life of the project (1990 through 1995), industry and DOE will invest more than \$100 million through cost-shared contracts aimed at improving PV manufacturing technologies. In addition to providing contract funding, the PV Program makes available its materials and device fabrication and analysis laboratories at NREL and at Sandia National Laboratories to help industry test concepts and analyze results.

In 1991, the PVMaT Project provided 22 U.S. PV companies with the opportunity and the resources to identify manufacturing process barriers and approaches to overcome these barriers. All these phase 1 contracts were completed in 1992. In phase 2 of the PVMaT Project, seven of these companies, under cost-shared contracts, are working to solve the process-specific problems identified in phase 1. By the end of 1992, these manufacturers had made significant progress in all three types of technologies: thin films, crystalline silicon, and concentrators, with several companies reporting substantially lower costs and higher production capacity directly attributable to PVMaT.

Photovoltaic Technology Validation

In 1992 and 1993, DOE continued to support PVUSA, a collaborative project among utilities, DOE, and state and local governments for installing and operating PV systems connected to utility grids. PVUSA is designed to give utilities the hands-on experience they will need to pro-

cure, evaluate, and use PV systems. Through PVUSA, PV manufacturers are gaining valuable market experience and a test-bed for their new products.

The project began in 1987 under the sponsorship of Pacific Gas and Electric Company of San Ramon, California, the Electric Power Research Institute, the California Energy Commission, and DOE. At the end of 1992, the consortium had expanded to include 7 states and more than 10 utilities. In 1992, the third round of procurement for PVUSA required successful bidders to build a 1-kilowatt version of the 20-kilowatt system they proposed to install at a PVUSA site. NREL and Sandia National Laboratories are testing the smaller versions.

Another PVUSA experiment in 1993 demonstrated the suitability of using PV to reduce loads on transmission and distribution equipment in a utility network, promising a large, value-added market. Analyses by Pacific Gas and Electric indicated that the output of a PV system coincided well with loads in its service area and that it could delay a needed conventional upgrading of the utility's Kerman substation, which would cost several million dollars, by using a 500-kilowatt PV array to support the substation during high loads. PVUSA decided to test the idea. Siemens Solar Industries, Camarillo, California, won the contract for the PV system and completed installation in 1993. The system is performing as predicted.

Photovoltaic Market Conditioning and Project Development

In 1992, as a result of targeted market conditioning, more than 20 utilities received direct technical assistance from the PV Program. Hundreds of key personnel from utilities attended DOE-funded workshops and conferences to learn how they could use PV.

DOE completed a project in 1992 that helped many utilities evaluate PV as a customer service alternative to line extensions. Eighteen utilities participated in cost-shared, offgrid water-pumping projects sponsored by the Department, the Electric Power Research Institute, and the Western Area Power Administration. After working with the PV systems, the utilities are evaluating ways to offer PV as a service option not only for pumping, but also for residential lighting. In 1993, one of the utilities, Idaho Power, received approval from the Idaho Public Utilities Commission to conduct a 3-year, \$5 million pilot program providing customers with PV-powered electric service.

In 1992 and 1993, the PV Program also worked with the Navajo Nation on several successful pilot projects that used PV for remote homes. In 1992, the Navajo Tribal Utility Authority decided to expand its use of PV as an

alternative to line extensions in rural areas—the tribe estimated that more than 4,000 rural homes currently had no electricity. The tribal authority is working with the Western Area Power Administration and Sandia National Laboratories to design, select, and install PV systems that bring electricity to more people who live in remote areas without electricity.

The PV Program is helping industry reach markets where PV is, or soon will be, cost-effective. In 1992, DOE published the Solar 2000 collaborative strategy. This strategy guides the PV Program's efforts to accelerate the commercial use of U.S. PV products. The strategy combines market-conditioning projects (both domestic and international), joint ventures among stakeholders, and technology development to synchronize the final stages of product development with end-use design and construction requirements.

Geothermal Energy

Geothermal energy resources (heat within the Earth) exist in four forms: hydrothermal (steam and hot brine), geopressured (hot brine under high pressure containing dissolved natural gas), hot dry rock, and magma (molten rock). DOE estimates the amount of energy contained in these resources at well in excess of 1 million quadrillion British thermal units (Btu) (1 million quads, or 1 million exajoules). For comparison, U.S. energy consumption from all sources in 1990 was about 81 quads (85 exajoules).

The only geothermal energy used commercially today comes from hydrothermal reservoirs that contain steam or hot water trapped underground in porous or fractured rock formations. Since 1960, commercial operations at The Geysers, California, have been generating electricity from naturally occurring dry steam, a geological rarity. Industry also has developed the more common hot-water hydrothermal resources for power generation, with plants operating in California, Nevada (Figure 2-1), Hawaii, and Utah. Figure 2-2 depicts the growth of geothermal electric power generation in the United States and projections based on current plans for building new plants. Half of the geothermal plants are located on lands leased from the Federal Government. Table 2-1 provides details about this income stream during recent years.

Geothermal powerplants that use steam and high-temperature liquids (more than 150 degrees Celsius (150°C)) comprise an electrical generating capacity of more than 2,500 gigawatts in the western states. Lower temperature hydrothermal liquids (50 to 150°C), and some at higher

2-1. Yankee-Caithness hot-water geothermal plant near Reno, Nevada.

temperatures, are used directly for space heating, aquaculture, mining, industrial processes, and other operations throughout the United States. These uses consume the thermal equivalent of more than 5.5 million barrels (750,000 metric tons) of oil annually. Hot rock, magma, and geopressured brines also could be used for electric power and direct applications, and geopressured brines could produce natural gas as well.

DOE's Geothermal Energy Program has supported R&D on all four resources. Current program efforts, however, place primary emphasis on those resources of greatest commercial interest, predominantly hydrothermal. In 1992 and 1993, the program emphasized cooperative, cost-shared research with industry and utilities as a preferred mechanism for technology development and transfer. Under this program, DOE sponsors scientific and engineering research leading to better understanding of geothermal resources and to technologies that can find these resources, access them, and convert them into useful energy.

Although industry has substantial experience in the commercial development of high-quality hydrothermal energy reservoirs, today's technology is economically marginal at all but the most favorable hydrothermal sites. Principal impediments include the difficulty of locating reservoirs and confirming their potential; the high cost of drilling wells into hard, hot rock in chemically hostile environments; the inefficiency of systems that convert low and moderate heat to electric power; the high chemical reactivity of geothermal brines; and uncertainties related to production from, and injection into, the underground geothermal reservoirs. The Geothermal Energy Program has placed a high priority on resolving these difficulties and lowering costs so that commercial development of geothermal resources can move forward more rapidly. The

2-2. U.S. geothermal electric power production, 1960-96.

program's goal is to lower the cost of power generated from moderate-temperature hydrothermal resources to a range of 3 to 7 cents per kilowatthour (1 to 2 cents per megajoule) in the midterm.

Reservoir Technology

DOE's geothermal reservoir technology research effort aims to minimize the risks associated with finding, characterizing, and producing hydrothermal resources. Most hydrothermal reservoirs producing power today were discovered by exploring in areas with surface manifestations, such as steam vents or hot springs. Sophisticated techniques will be necessary to locate the many reservoirs that remain hidden. Existing reservoir management practices must improve to increase the extraction of stored heat, reduce the corrosiveness of produced steam or brine, and lengthen the commercial lives of producing fields.

During 1992 and 1993, researchers at the University of Utah Research Institute (Salt Lake City) advanced capabilities for identifying hidden reservoirs by conducting successful electromagnetic field surveys in Nevada, New Mexico, and Utah. Development also continued on the cost-saving slim-hole drilling approach to reservoir exploration and assessment, including the selection of sites

where data taken in slim holes could be compared with data obtained from production-size wells.

Progress in reservoir management included the use of advanced microseismic measurement techniques to monitor the response of reservoir formations to fluid injection.

Table 2-1—Income from geothermal leases on Federal lands, 1980-92

Year	Income ^a
	(Dollars)
1992	16,806,316
1991	13,848,431
1990	17,042,338
1989	14,611,431
1988	13,246,043
1987	14,320,443
1986	17,381,944
1985	13,475,764
1980-84	17,357,248
Total	138,089,958

^aExcludes rental fees and bonus payments.

Researchers at Stanford University (Stanford, California) completed tests to determine the amount of water adsorbed on reservoir fracture surfaces and to estimate the potential energy recovery from that adsorbed water. Results from these studies support the development of better reservoir simulation models, which will lead to enhanced reservoir management techniques to extend reservoir lifetimes.

The Geothermal Technology Organization, a consortium of DOE and geothermal companies, continued jointly sponsored reservoir research, much of which was conducted at The Geysers, California. In 1992 and 1993, such efforts were concerned with corrosion mitigation, tracer development and testing, evaluation of fluid injection technology, and testing of reservoir management strategies. Two Geothermal Technology Organization projects investigated new interpretation methods for seismic data at the Coso geothermal field on the Navy's China Lake Weapons Range.

Hard Rock Penetration

Drilling represents 30 to 50 percent of the cost of geothermal power. Although the geothermal industry has adapted drilling technology from the oil and gas industry, geothermal drilling requirements are quite different from oil and gas drilling requirements. Much geothermal drilling involves hard, abrasive, fractured rocks, high temperatures, and highly corrosive fluids. All these factors impose exceptionally rigorous requirements on drilling systems.

In 1992 and 1993, DOE's geothermal drilling research projects focused on the control of lost circulation, exploration drilling technology, high-temperature instrumentation, and downhole signaling systems. Many of these projects are cost shared and are carried out under the auspices of the Geothermal Drilling Organization, another consortium that provides a mechanism for private companies to cooperate with one another and with DOE on research projects. Lost circulation is a serious, expensive, and potentially dangerous condition that geothermal drillers encounter frequently. To aid in early detection of lost circulation episodes, researchers have developed a rolling flowmeter that measures the rate at which drilling fluid exits a well. DOE loaned prototypes of the meter to industry for field-testing. Drilling fluids usually are lost through rock fractures encountered by a well, and such fractures must be plugged before drilling can continue. In 1993, engineers at Sandia National Laboratories completed the design of a drillable straddle packer, a downhole tool to direct pumped cement into a fracture system allowing drilling operations to resume with minimal cost and delay.

Exploration wells provide pathways for making measurements on underground rock formations, including geothermal reservoirs. The measurements are made with long, slim instruments lowered into the wells. The instruments developed for oil and gas exploration, however, typically do not work in hot geothermal wells. Scientists at Sandia have developed a downhole tool that carries a very cold liquid in an internal reservoir to cool sensitive electronic components. This tool contains a computer chip and memory that can record data for several hours in geothermal downhole environments. DOE-funded improvements in these tools will allow longer periods at high temperatures, producing better information about reservoir rocks.

Drilling is most cost-effective when drillers can get prompt data on downhole conditions. The current methods of transmitting these data up a well are quite slow (2 bits per second from mud pulsing). DOE-funded geothermal researchers at Sandia have developed a promising new concept that will greatly speed up the rate of data transmission, and they are cooperating with a major company to commercialize the invention. The technology will help reduce costs of drilling oil and gas wells, but geothermal drilling will receive a proportionally greater benefit. Because of temperature limitations, current methods cannot be used in geothermal wells.

The Department is also supporting work on improving drilling motor technology for geothermal service, upgrading cement formulations for use in geothermal wells, and developing an inexpensive technique for protecting geothermal well casing from corrosive chemical attack. In 1992, DOE geothermal researchers turned over to the drilling industry the design for an improved rotary head seal of the type now in use worldwide for oil and gas wells, as well as geothermal wells.

Energy Conversion Technology

The energy conversion system accounts for about one-half the capital cost of a geothermal power project. The challenges to designers of these conversion systems arise from the relatively low available energies and the corrosive chemistries of many hydrothermal resources. The DOE geothermal energy conversion program seeks to identify the most promising technology improvements, and then confirm them in joint projects.

In 1993, DOE selected two proposals for demonstrating improved electric generation technology for award of cooperative agreements. The first of these will use a biphasic rotary separator turbine on a flash steam power cycle; the

second will demonstrate use of a Kalina binary cycle using an ammonia-water mixture as the working fluid.

The Idaho National Engineering Laboratory continued research on increasing the efficiency of organic Rankine (binary) cycles by verifying the practicality of metastable supersaturated expansions in both impulse and reaction turbines. The first generation of an innovative thermally conductive polymer concrete liner for heat exchangers was field tested (Figure 2-3), while an improved version incorporating antioxidants was developed. The DOE Geothermal Energy Program also initiated cooperative projects with industry to develop carbon dioxide-resistant well cements and to improve the performance of heat rejection systems on geothermal plants.

In related research efforts, DOE sponsored the development of computer code programs for predicting the scaling and corrosion characteristics of geothermal brines. This computer simulation, developed by chemists at the University of California, San Diego, showed excellent correlation with field site data. The Department held a series of brine modeling workshops to promote the transfer of the technology to the geothermal energy community. DOE-funded research at Brookhaven National Laboratory addressed problems with residual brine wastes by constructing and operating a laboratory bioprocessing system that demonstrated the effective removal of undesirable materials, such as chromium, zinc, and manganese.

Geopressured Brines

A simple gravity system can capture the chemical energy in geopressured brines by separating the natural gas from the brines. In addition, electricity can be generated from the hydraulic and thermal energy contained in geopressured fluids. The major barriers to commercial exploitation of these resources are the high cost of drilling deep wells into high-pressure geologic formations and the current low price of natural gas.

During 1992, long-term flow tests of the Pleasant Bayou well in Texas provided more data on the response of a geopressured reservoir to production conditions. The Gladys McCall well in Louisiana remained closed during 1992 as researchers monitored the reservoir's long-term pressure recovery from earlier production. In 1993, DOE discontinued further research on geopressured geothermal energy to focus on hydrothermal energy.

Hot Dry Rock

The hot dry rock concept grew from ideas conceived in 1970 when a group of scientists and engineers at Los

2-3. Heat exchangers with polymer-concrete-lined tubes at site of field experiment.

Alamos National Laboratory reasoned that the vast store of energy in the crust of the Earth could be extracted by using hydraulic fracturing techniques already used by the oil industry. The hot dry rock process creates fissures in the rock and circulates water down an injection well and through the fissures, returning hot water for power production through one or more production wells.

The Los Alamos National Laboratory completed the first hot dry rock geothermal energy system in the world at Fenton Hill, New Mexico, in 1977. The Department enlarged it in 1979 by additional hydraulic fracturing and operated it successfully for more than a year. To extend the technology to the temperatures and rates of heat production required to support a commercial powerplant, DOE initiated construction of a much larger and deeper system at Fenton Hill in 1979.

Between April and July 1992, DOE conducted a flow test of the larger reservoir. During the 4-month test, the reservoir produced thermal energy continuously under constant operating conditions at an average level of about 4 megawatts. Results of the experiment, including the plant's availability, thermal drawdown, and water consumption, were all very encouraging and were replicated in a second flow test in early 1993. However, the Fenton Hill operations are on standby pending the results of a notice of interest to cost-share a commercial hot dry rock venture.

Geothermal Heat Pumps

In 1992, DOE initiated a series of three national teleconferences on geothermal heat pumps with the Environmental Protection Agency, the Electric Power Research Institute, the National Rural Electric Cooperative Association, the

Edison Electric Institute, the International Ground Source Heat Pump Association, and other interested groups. The first teleconference, designed for utilities and government officials, was viewed by more than 3,500 people at hundreds of sites nationally. The second teleconference was aimed at dealers and contractors, and the third was aimed at architects and engineers.

Research efforts are under way to reduce the cost of installing ground heat exchangers for both residential and commercial buildings. In conjunction with the National Rural Electric Cooperative Association, DOE is evaluating drilling systems for installing residential ground loops with a minimum of surface disturbance, which will not only protect landscaping but also allow installation on small urban lots, and for installing ground loops in 1 day (which will facilitate retrofits). To assist utilities in developing integrated resource plans, researchers are collecting the limited available data to identify the value of geothermal heat pumps in reducing utility summer and winter peakloads and improving utility load factors.

Solar Thermal Electric Systems

Solar thermal electric systems use mirrors to concentrate the Sun's radiation. This concentrated sunlight can be used to heat working fluids for electricity generation or process heat, or it can be used directly in a variety of photochemical processes. Primary system designs use either a central receiver surrounded by a field of mirrors (power-tower systems) or distributed receivers mounted at the focal points of parabolic dish or trough concentrators (Figure 2-4). Although solar thermal systems can serve a variety of thermal applications, electricity generation may have the greatest potential.

Commercial Applications

Solar thermal electric systems have entered the U.S. electricity market. Present parabolic trough systems have an installed capacity of 354 megawatts. These powerplants are all currently supplying electricity to the utility grid in southern California. Much of their unique and valuable experience is being shared with developers of next-generation powerplants. Operators of five of these solar power stations, accounting for 150 megawatts, have joined with DOE in a \$7 million, fifty-fifty cost-shared program to reduce operation and maintenance costs associated with these plants; the lessons learned will be applicable to the 100- to 200-megawatt commercial power-tower plants to

2-4. Types of solar thermal systems used to concentrate sunlight to heat fluids for electricity generation or other thermal or photochemical processes.

be built by the year 2000. Solar Thermal Electric Program-sponsored development of new solar concentrators and receivers and solarization of electric conversion systems (engine generators) should allow industry to expand this capacity and to introduce power-tower and dish-engine technologies into the utility marketplace by the year 2000. To facilitate this, during 1993 DOE developed a comprehensive 5-year plan in collaboration with industry and other key players to map out a strategy for developing and commercializing the solar thermal electric technologies by the end of the decade, primarily through fifty-fifty cost-shared joint ventures between the Department and industry.

Industry is interested in developing dish-engine systems for the remote market (10 to 20 cents per kilowatthour (3 to 6 cents per megajoule)), with 5- to 10-kilowatt systems providing early nongrid deployment and commercial opportunities, and in using such systems as technological stepping-stones to less expensive technologies for utility applications. Cummins Power Generation, of Indiana, is fifty-fifty cost-sharing a 4-year, \$16 million effort to commercialize a 7.5-kilowatt dish-engine system for these remote applications. In 1992, the first phase of this three-phase program was successfully completed, and units were operating in Abilene, Texas, and Lancaster, Pennsylvania. In 1993, Cummins installed an additional power system in southern California. These systems use simple free-piston Stirling engines and linear alternators in com-

bination with liquid-metal heat pipe receivers pioneered by DOE's Solar Thermal Electric Program.

Larger dish-Stirling engine systems are also being considered, and in 1992, three industry teams submitted technically qualified proposals to develop, again on a fifty-fifty cost-shared basis, 25-kilowatt dish-engine systems for peaking and intermediate utility plant applications. These teams included the Science Applications International Corporation of Golden, Colorado; Cummins Power Generation of Columbus, Indiana; and Hydrogen Engineering Associates of Mesa, Arizona.

Power-tower systems for intermediate utility markets are designed to achieve high capacity factors by using integral thermal storage, enabling the utilities to meet peak demands consistently, and thus to accrue full capacity credits even during periods of low insolation. Southern California Edison (Rosemead, California) is leading a private-sector consortium of western utilities and others in a \$48 million fifty-fifty cost-shared program with DOE to retrofit the 10-megawatt Solar One power tower with energy collection and storage systems based on molten nitrate salts in order to validate this technology on a utility scale. This effort, called Solar Two, will provide the basis for the first 100-megawatt commercial power towers. Plant design began in 1993, and construction will begin in 1994.

In addition to these large-scale cooperative activities, Solar Thermal Electric Program personnel continued in 1992 and 1993 to work closely with industry and utilities through the Committee on Renewable Energy Commerce and Trade and through the Design Assistance Center at Sandia National Laboratories.

Technology Development

Concentrator Research

Concentrators represent the largest single cost of today's solar thermal systems. DOE supports research to reduce this cost by developing new reflective films and concentrator designs. Tests have confirmed the achievement of a major program goal for reflective films: 90-percent reflectivity in a durable film. Research on concentrators has involved performance testing of heliostat and dish designs, including multifaceted dishes, that incorporate glass and stretched-membrane reflective surfaces. In addition, industry has designed and fabricated prototype high-performance commercial heliostat units with 100-square-meter stretched membranes and projected durability of more than 5 years; these units are undergoing long-term testing at Sandia National Laboratories. Re-

searchers have completed the design, fabrication, and initial testing of a reflective high-performance stretched-membrane dish concentrator that is 7 meters in diameter. Other researchers have addressed other aspects of dish design, including support structures and tracking mechanisms. Research is continuing on the design, fabrication, and testing of 85-square-meter multifaceted dishes with 3-meter-diameter stretched-membrane facets. The membrane reflectors have exhibited excellent optics, and ongoing full-dish system tests incorporating these facets will continue through 1993.

Power Conversion Development

DOE's power conversion development effort support solar commercialization activities by addressing the solar-specific needs of the cooperative projects. The Solar Thermal Electric Program responds to industry's requests for development of concentrators, solar receivers, transport and storage systems, and system controls for both power-tower and dish-engine electric systems. Research on power-tower systems in 1992 and 1993 focused on issues directly relating to Solar Two, including salt flow control, material compatibility, and the development of unique instrumentation to evaluate properly the performance of Solar Two.

A critical element in the development of dish-engine systems is the substitution of reflux receivers for tube receivers. The engine heater head tubes must sustain internal helium pressures of up to 120 atmospheres (12 megapascals) and withstand temperatures up to 800°C. A subatmospheric-pressure liquid-to-metal heat transfer process takes place in the reflux receiver. This process eliminates the stresses imposed on the heater head by the temperature variation caused by direct exposure to the solar flux. In tests through early 1993, prototype receivers demonstrated 90-percent efficiency at 800°C and transmitted more than 65 kilowatts of thermal power.

Wind Energy

The DOE Wind Energy Program is working in partnership with utilities and industry to foster multiregional U.S. markets for wind systems and to establish the United States as the world leader in the development and use of advanced wind turbine technology. To this end, the program has adopted the program objectives of increasing utility use of wind energy, developing advanced wind turbines, in-

creasing productivity and industry competitiveness, and upgrading the applied research base.

Adequate wind resources for cost-effective energy production are found in all regions of the United States, although the Midwest, West, Northwest, and Northeast tend to have the best winds. Even with modest development of these resources, wind can make a major impact on the country's energy supply. The Pacific Northwest Laboratory reports that more than 50 quads (53 exajoules, equivalent to 2,200 gigawatts of generating capacity) of wind energy is available from potential sites with at least a class 4 wind resource (a site with higher than 5.6 meters per second (12.5 miles per hour) average annual wind speed measured at 10 meters above the ground). Figure 2-5 shows these potentially available windy lands.

Technology Status

Wind energy has proven to be the most cost-competitive and most used advanced renewable energy technology for the bulk power market. Of the 2,000 megawatts of wind generating capacity interconnected with utilities worldwide, nearly 1,600 megawatts is installed in the United States. This U.S. capacity comprises nearly 16,000 turbines, averaging about 100 kilowatts capacity per unit. In 1992, wind plants in California produced nearly 3 billion kilowatthours (11 petajoules) of electric energy. Installations in the early 1980s had reliability and performance problems, but the industry has improved the technology to the point that today's utility-interconnected turbines produce power at costs of 7 to 10 cents per kilowatthour

2-5. Average annual wind power in the United States.

(2 to 3 cents per megajoule) at a 5.8-meter-per-second (13 mile-per-hour) site, rivaling many nonrenewable sources.

Several utilities have announced plans to install wind powerplants in their service territories. For example, the Bonneville Power Administration, a Federal power marketing administration for the northwestern United States, has committed to an initial 50 megawatts of wind-generated electricity to be online by 1995. Utilities in Iowa, Minnesota, Montana, and New England have similar plans.

Research Direction

DOE's major wind technology research challenge is to improve the technology's cost-effectiveness. The national laboratories, in close cooperation with the U.S. wind industry and electric utilities, conduct research activities to that end. NREL is the lead center for program planning and integration, wind turbine research and technology, the development of advanced turbines, and conduct of cooperative wind technology applications research. Sandia National Laboratories provides support for fatigue and materials research in cooperation with NREL. Pacific Northwest Laboratory emphasizes wind characterization and wind resource assessment.

National Wind Technology Center

Recently, DOE announced that it plans to establish the National Wind Technology Center at Rocky Flats, Colorado. This facility will provide the United States with a world-class wind energy R&D center. This facility will also be the new location for the NREL wind technology R&D staff. It will provide a new utility-scale research turbine, specialized component test facilities, computer modeling facilities, and a turbine test capability for use by industry.

Utility and Industry Programs

DOE is pursuing a variety of research activities that will help it achieve its Wind Energy Program goals of widespread utility use and regional diversity of installations. Included in these activities are the Advanced Wind Turbine Program, the Utility Integration Program, and the Collaborative Wind Technology Program.

Advanced Wind Turbine Program

The Advanced Wind Turbine Program will assist industry efforts to incorporate advanced wind turbine technol-

ogy into commercial machines for the near term (1993 to 1995), and to provide the next generation of utility-grade wind turbines for the midterm (late 1990s). Under the near-term product development activity, three new prototype machines are now being field-tested, and a fourth is being developed. They range in size from 50 to 300 kilowatts (Figure 2-6). Development of components for next-generation turbines has also begun. The benefits of this program will be to introduce new products into the marketplace, create greater stability and strength in the wind industry by attracting utility participation, broaden the regional use of wind energy, foster the formation of new development teams, and increase competitiveness in the international marketplace.

Utility Integration Program

The Wind Energy Program has initiated a series of activities to help electric utilities address their questions about integrating wind systems into their normal operations. An important mechanism for providing guidance for program efforts in this area is the cooperation with the utility industry through the Utility Wind Interest Group, a joint effort of the Electric Power Research Institute and DOE.

2-6. Lightweight Carter 300-kilowatt wind turbine.

DOE's Utility Wind Turbine Verification Program is a joint effort between the Electric Power Research Institute and the DOE Wind Energy Program. The goal of this major new activity is to deploy and evaluate commercial and prototype wind turbines in typical utility operating environments. This collaboration provides a means to bridge the technology gap between advanced turbine development activities and utility purchases of wind turbines. Three host utilities have been selected to deploy and evaluate a wind plant using advanced turbines (nominally 20 at each host site, or approximately 6 megawatts). Machines will be installed and tested over the next several years.

Collaborative Wind Technology Program

The Collaborative Wind Technology Program's activities with industry are numerous and varied. DOE has initiated a value-engineered turbine activity to assist the U.S. wind industry in applying new technology to improve the performance of commercial wind turbines for both the domestic and the international marketplaces. Industry proposals have been requested, and contracts are being negotiated for reengineering or remanufacturing conventional wind turbine configurations that have proven to be reliable suppliers of electricity in California and Europe. These efforts will help the wind industry seek near-term opportunities, both domestic and international, for wind energy.

Applied Research Program

Industry-driven applied research is necessary to ensure that fundamental design tools will be available for industry use in performing detailed designs of future advanced wind turbines. DOE's Applied Research Program has developed computer models for aerodynamic performance, structural dynamics, and yaw dynamics that run on personal computers. The program's midterm research activities look beyond the immediate needs of industry, and they require some risk taking, because they may not receive the immediate support of industry and technical pay-offs may not be realized for several years. An example of such an activity is recent research that provided a wealth of quantitative and flow visualization data on the aerodynamic behavior of stalled wind turbine blades, which will benefit U.S. turbine manufacturers for years to come. When advanced stall-controlled rotor designs are developed, these data will be invaluable to U.S. designers.

TRANSPORTATION TECHNOLOGIES

Introduction

The transportation sector needs to develop economically competitive alternative fuel sources to reduce its 97-percent dependency on petroleum-based fuels. The supply-related R&D activities of the Transportation Technologies Program aim to develop performance- and price-competitive alternative fuels derived from biomass and other renewable energy resources and to resolve problems with the use of non-petroleum-based fuels in vehicles. Alternative fuels, including biofuels, hydrogen, and electricity, could replace petroleum with domestic renewable resources, reducing the Nation's need to import petroleum and thereby increasing the Nation's economic and energy security. Alternative fuels could also reduce vehicle emissions. In fact, current interest in alternative fuels derives, to a large extent, from their potential for improving environmental quality.

Biofuels

The primary goal of the Biofuels Program is to provide the technology base and infrastructure required to introduce by the year 2000 domestically produced, economically viable renewable transportation fuels that are competitive with petroleum-based fuel without subsidies. Beyond 2000, the Department projects that the cost of biomass-derived fuels and blending components will be reduced to the point where they will be cost-competitive with petroleum-based fuel and component alternatives. Because of the large potential U.S. biomass resource base, the widespread use of program-sponsored biomass technologies and fuels could reduce U.S. oil imports, create thousands of U.S. jobs in rural and urban areas, and reduce air pollution in many of the Nation's urban population areas.

To help achieve its goal, the program must work with industry to develop low-cost biomass feedstock production technologies and cost-competitive high-yield conversion technologies. Recognizing that the successful deployment of the program's technologies will be impossible without industry participation, in 1993 DOE began a strategic planning process to more closely align the pro-

gram with the goals and objectives of industry participants. The resulting program will be more focused on industry interests and near-term marketplace opportunities.

Building on more than a decade of steady progress in research on biomass feedstock development and conversion process engineering, the Biofuels Program is now entering a crucial technology scale-up and demonstration phase. Proof of the value of its research is found in the private sector's willingness to enter into cost-share partnerships. These industry partnerships effectively leverage DOE funds while providing valuable industry insight into the most cost-effective approaches and also building constituencies for the products of program efforts. The core scientific-capability and research results from DOE-supported work at national laboratories, private industry, and university contractors have produced two cooperative research and development agreements (CRADAs), one multi-industry consortium, and three industry demonstration projects representing a wide range of industry participants. This process is expected to expand in the 1994-1995 period, both in the conversion technology and in the feedstock development.

Feedstock Development

Development of low-cost feedstocks includes research on the selection and management of terrestrial and aquatic plant species that can be grown specifically as feedstocks for liquid-transportation-fuels production. Terrestrial, or "land-based" feedstock research includes dedicated short-rotation woody and herbaceous energy crops. The aquatic program focuses on the improvement and use of microalgae. In both programs, increasing the yield and reducing the cost of energy crop feedstock production are critical for biomass-based fuels to significantly contribute to transportation fuel supplies. The Feedstock Program's goals are to develop the technology to make it possible to produce terrestrial feedstocks at an average cost of \$2.00 per million British thermal units (\$1.90 per gigajoule) by the year 2000, with average annual yields of 8 to 10 tons per acre (3 to 4 metric tons per hectare), and to increase the yields of microalgae to the point where they are competitive with diesel and diesel fuel substitutes by the year 2010.

The program's most recent significant accomplishment was the success of the first full-year joint research collaboration between the Department, various industry groups, and universities through The Consortium for Plant Biotechnology Research, Inc. This consortium is a multi-million dollar jointly funded feedstock research effort rep-

resented by more than 38 corporate members, 22 universities, and 1 national laboratory. Through this consortium, the program will leverage its resources to undertake research that is meaningful to industry, while meeting overall program objectives.

Under the terrestrial crop program, the major model wood energy source that DOE is developing is the genus *Populus*, which includes aspens, cottonwoods, poplars, and various intra- and interspecies hybrids. *Panicum virgatum*, a native switchgrass species, has been chosen for development as the herbaceous energy crop model.

Building on past efforts, current *Populus* research is focused on the Pacific Northwest and North Central regions, with a new program in the Southeast region. In the Pacific Northwest, the University of Washington and Washington State University have spearheaded a well-integrated, multidisciplinary project since the early 1970s that has produced *Populus* hybrids that have doubled the yields of native clones. Industrial plantings using research developed under this program have increased to more than 19,000 acres (7,689 hectares), which is an almost 100-percent increase over the 1992 total. In the Southeast, the program has completed competitive request for proposal reviews and has selected projects. Research results from the new region should be available by early next year.

For many reasons, switchgrass is an ideal model herbaceous species for development. Because it is a widely adapted species of the tallgrass prairies, switchgrass has a deep-rooted habit, which not only contributed to the deep, rich soils found by early settlers but also contributes to its ability to grow on relatively poor sites where many conventional crops could not be produced. As reported in 1992, test plots in Auburn, Alabama, have shown maximum yields of 15 dry tons per acre (34 metric tons per hectare) per year, well above the minimum level of production estimated for a successful biofuels industry; and in 1993, higher-than-expected productivity results were achieved in Texas. Recent advances in biotechnology and in the genetic understanding of switchgrass could reproduce or even enhance these results in other areas of the United States.

The aquatics feedstock program primarily focuses on microalgae, which are microscopic aquatic plants with the potential to produce large quantities of lipids (plant oils) that can be extracted and converted into an ester fuel, a diesel fuel substitute. Microalgae have high growth rates and tolerance to varying environmental conditions. The yield per acre for microalgae is three to five times greater than the yield for "typical" or "terrestrial" crop plants. Genetic engineering has been an important aspect of the

Department's ongoing effort to increase lipid yields and reduce fuel production costs. Continuing with successful key gene cloning and detailed gene structure research, the program has now developed genetic markers for rapid detection of successful genetic transformation and expression in recombinant organisms. The program has also constructed a plasmid vector containing an expressible form of acetyl-CoA carboxylase gene, a key lipid production enzyme. Additionally, efficient protocols for culture collection, maintenance, and viability have been developed. All of these accomplishments will allow the program to more accurately verify test results, while more clearly understanding how to increase microalgae lipids production and thereby reduce the cost of the feedstock and ultimately the fuels derived from it.

Conversion Technologies

The Department's conversion research addresses the production of liquid fuels from biomass feedstocks through biochemical and thermochemical processes. Current research focuses on reducing the costs of biochemically converting biomass into ethanol and thermochemically converting biomass into methanol and high-value reformulated gasoline components, so that these technologies will be competitive with petroleum-based fuels by the year 2000 without subsidies. The overall cost goals are to develop technology to produce ethanol from biomass for \$0.67 per gallon (\$0.18 per liter) and to produce other cost-competitive biomass-derived fuels, such as methanol, for \$0.50 per gallon (\$0.13 per liter).

DOE's biochemical conversion research emphasizes ethanol production and searches for methods to convert all parts of the feedstock, including cellulose, hemicellulose, and lignin, into fuels. In 1993, researchers at the National Renewable Energy Laboratory (NREL) continued to develop the simultaneous saccharification and fermentation (SSF) process, which combines the enzyme-catalyzed breakdown of cellulose into glucose with the fermentation of glucose into ethanol in a single reactor. To assist in this research, recombinant cellulase genes were cataloged, and a first generation of multigene cellulase expression systems was begun to combine different enzyme genes in the same host cell. Both of these research documentation techniques should lead to the identification of improved enzymes that will enhance overall process efficiencies and lower costs.

Progress on new enzymes to catalyze the breakdown of cellulose has led to key patents for several temperature-resistant cellulases isolated by NREL researchers. It is

estimated that program advances have reduced the estimated cost of converting biomass into ethanol from \$1.27 in 1992 to \$1.22 (1990 dollars). Also in 1993, researchers conducted a pilot-scale study of a novel dilute acid pretreatment process that may allow for a more efficient and cost-effective means of pretreating biomass feedstocks. In addition, an integrated bench-scale of the simultaneous saccharification and fermentation conversion process was completed and tested. This bench-scale unit is providing important design and process information for a process development unit currently under construction.

NREL's first-of-a-kind biomass-to-ethanol pilot facility, which is scheduled for startup in early 1994, will demonstrate ethanol conversion technology at the scale of 1 ton (0.9 metric ton) of biomass per day. Another major activity involves the CRADAs with industrial partners. Two CRADAs are in place: one with the New Energy Company of Indiana, and one with the Amoco Oil Company. Both CRADAs, with their initial experimental successes, are expected to continue, and the startup of the NREL pilot facility should bring increased industry involvement in 1994.

Thermochemical conversion research focuses on developing low-cost, efficient thermochemical processes to convert biomass into: (1) biosyngases, via gasification, that can be used as gaseous fuels or further processed into liquid fuels such as methanol and (2) olefinic compounds for ethers and other components, via pyrolysis, for reformulated gasoline. In the past year, biosyngas research has led to the synthesis of new catalysts and an enhanced understanding of their physical properties. One of the most promising involves new catalysts under study at the engineering-unit scale using the Battelle Columbus Gasifier. Further research to verify early results is ongoing.

Biomass-to-reformulated-gasoline-components research is receiving increased attention by the program and industry for near-term commercial applications because of changes in the gasoline pool mandated by the Clean Air Act Amendments of 1990. As such, the program has established an industrial partnership strategy and is currently conducting an economic evaluation of potential program end-products that would be the most useful to industry. One potentially useful low-cost feedstock is refuse-derived fuel for conversion, via pyrolysis, into high-value ethers such as ethyl tertiary butyl ether and methyl tertiary butyl ether. To test the conversion of refuse-derived fuel, a pilot-scale plant is under construction at NREL that uses NREL's vortex reactor. The pilot plant is scheduled to be operational in late 1994. In addition, a larger pilot plant is being built in cooperation with industry. A 35-ton-per-

day (32-metric-ton-per-day) pilot plant using the vortex reactor is being built at Interchem's facilities in Kansas. This plant is also expected to be operational by the end of 1994.

Alternative Fuels Use

The use of alternative fuels in place of conventional gasoline and diesel fuels could significantly reduce the Nation's dependence on petroleum and reduce emissions from vehicles. DOE's Alternative Fuels Utilization Program encourages the use of non-petroleum-based fuels in compliance with clean air standards. Barriers to the widespread implementation of alternative fuels are partially fuel specific, but they include an inadequate supply and distribution infrastructure, the high cost of low-volume production, and underdeveloped utilization technology. The program addresses deficiencies in data or utilization technology by developing a technology base for the use of synthetic, alcohol, and gaseous fuels (natural gas, propane, hydrogen) in contemporary and advanced engines. Research supported by the program ranges from fundamental bench-level experiments to emissions and fuel economy characteristics of alternative-fuel vehicles in service. Current program activities fall into the areas of R&D and alternative-fuel fleets.

Research and Development

The R&D projects of the Alternative Fuels Utilization Program are currently addressing oxygenated fuels (methanol, ethanol, ether), and gaseous or liquefied fuels (natural gas, propane, hydrogen). The projects are concentrated in three main areas: fuel properties, engine systems, and emissions and environmental studies.

Fuel Properties

In 1992 and 1993, DOE continued to direct considerable work toward the generic problem of isolating the key chemical and physical properties that dominate fuel's combustion and emission characteristics. Recent initiatives involving natural gas included an analytical study of liquefied natural gas to fully characterize its properties as a motor fuel and the identification of the impact of compressed natural gas composition on vehicle operation and emissions through engine and vehicle testing, as well as research into direct-injection, liquefied-natural-gas engines.

DOE is also collecting emissions data from heavy-duty engines operating on biodiesel, a biodegradable derivative of soybean oil; reviewing a variety of clean diesel formulations aimed at reducing particulate emissions; and tracking the development efforts of industry in formulating gasolines to meet future air quality standards. The Alternative Fuels Utilization Program also sponsors research to demonstrate the use of hydrogen-methane blends in vehicles; developing, demonstrating, and testing a direct-injection, hydrogen-fueled engine; and engineering a new combustion chamber and inlet port design for eliminating abnormal combustion in a hydrogen engine. DOE uses its Alternative Fuels Production Center at the Southwest Research Institute to produce special test fuel formulations for use in engine testing programs, as well as a repository of alternative fuels that have been produced over the last 20 years.

Engine Systems

DOE's alternative-fuel engine systems R&D projects are centered on the adaptation of existing light- and heavy-duty engines and the development of new light-duty engine concepts for alternative fuel use. Testing and evaluation of commercially available light-duty conversion kits is now being conducted by the Institute of Gas Technology for compressed natural gas and Southwest Research Institute for liquid petroleum gas. In addition, the program is supporting the development and demonstration of a four-cylinder turbocharged engine operating on M-85 (85 percent methanol, 15 percent gasoline) at the University of Tennessee at Knoxville.

With the certification of its 6V92TA engine on methanol and ethanol completed, Detroit Diesel Corporation (Detroit, Michigan) has turned its attention toward natural gas engine technology. The company is studying in-cylinder ceramic coatings and catalytic glow plugs to improve ignition, and it is testing exhaust oxidation catalysts for unburned methane reduction. Caterpillar Inc., (Peoria, Illinois) has demonstrated a fuel sensor that can discriminate the fraction of methanol in methanol-diesel fuel mixtures.

Emissions and Environmental Studies

In a cooperative agreement with the Coordinating Research Council, DOE is conducting 13 projects to investigate the atmospheric reactivity of alternative-fuel vehicles. The projects are being conducted at national laboratories, research firms, and university laboratories. In addition, the

Transportable Engine Emissions Testing Laboratory developed at West Virginia University (Morgantown) continues to test a variety of heavy-duty alternative-fuel vehicles, including buses and trucks, throughout the country (Figure 2-7). Due to the success of this laboratory and the demand for its use, DOE is planning to fund a second mobile laboratory.

Alternative-Fuel Fleets

DOE conducts vehicle fleet demonstration projects in support of the Alternative Motor Fuels Act of 1988, which provides for demonstration, tests, and studies pertaining to alternative-fuel vehicles. The Energy Policy Act of 1992 establishes a procurement schedule for light-duty alternative-fuel vehicles for the Federal fleet, and Executive Order 12844 calls for even greater alternative-fuel vehicle acquisitions than those required by the Energy Policy Act. The Department has collected 5-year plans for alternative-fuel vehicle acquisition by Federal agencies and is working with the General Services Administration to develop alternative-fuel vehicle procurement requests. The Department has initiated the Clean Cities Program to enhance the coordination of alternative-fuel vehicle initiatives required by legislation and executive orders with initiatives of state and local governments and private industry. The major objectives of the program are to bring together city, local, and state governments, industry, consumers, and the Federal Government to deploy large numbers of alternative-fuel vehicles in selected, concentrated cities and regions and to promote the establishment of a self-sustaining, cost-effective alternative-fuel infrastructure.

The Alternative Fuel Fleets Program is currently collecting data from approximately 4,400 vehicles located at various sites around the country. These vehicles are distributed among the Federal (light-duty), heavy-duty, mass transit, military, and off-highway vehicle groups for fleet testing and operations. The data collected from these fleet demonstrations are transferred by DOE-funded contractors to the Alternative Fuels Data Center, located at NREL. The center has established remote access to the data for original equipment manufacturers.

The Department works with each Federal agency that purchases vehicles to coordinate the increased use of alternative-fuel vehicles to meet EPACT and Executive order requirements. The General Services Administration (GSA) plays a major role by awarding contracts for the procurement of alternative-fuel light-duty vehicles under an interagency agreement with DOE. Each agency that purchases vehicles can order vehicles from the GSA con-

2-7. The West Virginia University Mobile Emission Laboratory testing a natural gas-powered transit bus.

tract, including the U.S. Postal Service and the Department of Defense. In addition, GSA operates an Interagency Fleet Management Service (IFMS) that each year purchases and leases 40,000 vehicles to the agencies. In 1992, GSA-IFMS procured and placed into service 2,500 methanol-fueled vehicles, 675 natural-gas-fueled vehicles, and 25 ethanol-fueled vehicles in Bakersfield, Los Angeles, and San Diego, California; Denver, Colorado; Chicago, Illinois; New Orleans, Louisiana; New York, New York; El Paso and Houston, Texas; and Washington, D.C. In 1993, GSA-IFMS purchased an additional 3,200 vehicles, including 2,500 additional methanol sedans and 400 natural gas trucks and vans. The Postal Service converted 1,400 vehicles to natural gas, and the Department of Defense converted 800 vehicles to natural gas. Other agencies purchased or converted approximately 1,100 vehicles, bringing the total Federal fleet acquisition/conversion of alternative-fuel vehicles for 1993 to approximately 6,500 vehicles.

The heavy-duty fleet (481 vehicles) consists of three classes of trucks: school bus, delivery, and heavy commercial. The National Institute for Petroleum and Energy Research is collecting performance and drivability data from a fleet of 50 Tulsa (Oklahoma) School District school buses that use compressed-natural-gas Hercules engines. The delivery fleet consists of 110 original-equipment-manufactured alternative-fuel trucks being operated by Federal Express, 10 converted compressed-natural-gas trucks operated by the United Parcel Service, and 8 converted compressed-natural-gas trucks operated by the U.S. Postal Service. In a cost-shared program with New York City, six alternative-fuel refuse packers are in service with

the New York Department of Sanitation. A compressed-natural-gas over-the-road truck is being operated in a fleet in California. Archer Daniels Midland (Decatur, Illinois) and the State of Illinois operate five ethanol tractors in a cost-shared project with DOE.

The Alternative Fuels Bus Project uses Alternative Motor Fuels Act funds to test alternative-fuel transit buses in conjunction with the Federal Transit Administration's Alternative-Fuel Initiative Program with state and local agencies. The project continues to collect data to assess the durability, safety, fuel economy, and emissions of natural-gas and methanol buses from numerous transit authorities.

The DOE Program also supports the operation of alternative-fuel fleets at Tinker Air Force Base, Oklahoma, and Fort Bliss, El Paso, Texas. In addition to these efforts, the Department is planning to participate in a cooperative research program aimed at demonstrating the environmental and economic benefits of using natural gas as a locomotive fuel, and it operates a national toll-free Hotline for public inquiries on alternative fuels.

Education and Training

DOE's expanding educational and training activities focus on creating new educational opportunities and promoting interest in technology at the elementary school, high school, college, and industry levels. Many of these activities draw on DOE's unique laboratory facilities and relationships with trade and scientific associations.

Recognizing the important roles that today's students will play in developing and applying tomorrow's advanced technologies, the DOE Transportation Technologies Program sponsors student competitions in concert with the Society of Automotive Engineers, automobile manufacturers, and other organizations. These competitions have been very successful in stimulating student efforts and interest in alternative fuels.

The 1993 Hybrid Electric Vehicle Challenge (sponsored by DOE, the Ford Motor Company, and the Society of Automotive Engineers) took place in June 1993 in Dearborn, Michigan. Students from 30 U.S. and Canadian universities built range extender hybrid vehicles for the event: at each of 18 schools they converted a Ford Escort, and at each of 12 schools they built a vehicle from the ground up. The University of Alberta won the conversion class, and Cornell University won the ground-up class. The most efficient electrical system was 163 miles per gallon (69 kilometers per liter) gasoline equivalent, and

the most efficient heat engine system was 53 miles per gallon (23 kilometers per liter). These hybrid vehicles will compete near Detroit, Michigan, in the 1994 Hybrid Electric Vehicle Challenge. The competition will also include 12 Saturns converted to run as power assist hybrids that do not need to be charged from the electrical grid.

In the 1992 Natural Gas Vehicle Challenge, 20 university teams from the United States and Canada came to the General Motors proving grounds in the Detroit area and competed in the categories of fuel efficiency, emissions, and performance with pickup trucks that students had converted to operate on natural gas (Figure 2-8). The trucks showed substantial improvements since the 1991 Natural Gas Vehicle Challenge. Major sponsors of the 1992 competition, in addition to DOE, included General Motors Corporation, the Society of Automotive Engineers, the Environmental Protection Agency, and the natural gas industry. The 1993 Natural Gas Vehicle Challenge took place in Austin, Texas, in June 1993 and involved 23 universities (with the first entry from Mexico). The cleanest vehicle (from the University of Texas at El Paso) had half the California ultralow-emissions-vehicle emissions standard.

DOE sponsored events and prizes at several other vehicle competitions. In March 1993, 24 high school teams converted vehicles to operate on battery power alone at the Phoenix 500 in Phoenix, Arizona. The teams were judged for vehicle design, oral presentation, vehicle range, and vehicle efficiency. The most efficient vehicle obtained a 190-mile-per-gallon (80-kilometer-per-liter) gasoline equivalent. Argonne National Laboratory performed tests at the Atlanta Clean Air Grand Prix, Atlanta, Georgia, in May 1993 for efficiency and range on electric vehicles designed by 10 colleges and universities from the South-

2-8. Student competitors and their entries at a Natural Gas Vehicle Challenge Event.

eastern United States. For the first time, Historically Black Colleges and Universities participated in a major student vehicle competition. Central Florida University was the overall winner. Also in May, DOE gave prizes to the most efficient student vehicles in the American Tour de Sol, which traveled from Boston, Massachusetts, to Burlington, Vermont.

Information Collection and Dissemination

There are several ongoing and future information collection and dissemination activities designed to provide DOE, the public, industry, and the scientific community with methods to exchange data on transportation technology and alternative fuels. The National Alternative Fuels Data Center at NREL provides decision-makers in government and industry with standardized, compatible, and reliable information on alternative fuels and their performance characteristics (Figure 2-9). DOE has printed and distributed approximately 4.2 million copies of the congressionally mandated *Gas Mileage Guide* to the public through car and light-truck dealers. The guide provides reliable comparative data on the fuel economies of available new car models (based on Environmental Protection Agency estimates), along with consumer information and energy-conserving driving tips. Data provided included an annual fuel costs chart, factors that can raise or lower fuel economy, and sources for obtaining additional copies of the *Gas Mileage Guide*.

2-9. The Alternative Fuels Data Center, operated by the National Renewable Energy Laboratory in Golden, Colorado.

Technology Transfer

Technology transfer is an integral part of the DOE Transportation Technologies Program, because it helps ensure that results of program R&D are effectively conveyed to those who will use them. Given the nature of the transportation industry and the technologies that the Department is developing, the primary audience for technology transfer is not the consumer, but rather engine, battery, and vehicle manufacturers and related engineering firms.

The Transportation Technologies Program has worked to establish close, cooperative relationships with industry. As a general rule, the program's activities are structured to maximize industry participation in both planning and implementation, and they emphasize collaborative R&D with industry in the development of key technologies. This approach facilitates the rapid transfer of technical results and information to the industries (engine, battery, and vehicle manufacturers) that will be directly involved in commercializing them. Nearly two-thirds of Transportation Technology Program funds are used to support private-industry R&D. The cooperative agreement with the U.S. Advanced Battery Consortium marks a milestone in government-industry collaboration on a critical technological development. A number of cooperative research agreements were also initiated between industrial organizations and DOE laboratories for vehicle and fuel technology development. DOE recently signed two major cost-shared contracts with industry teams led by General Motors and Ford for hybrid vehicle development.

Throughout 1992 and 1993, the Department used a variety of technology transfer mechanisms, including contractor coordination meetings, information dissemination via professional networks, participation in internal technology exchange agreements, establishment of user centers for selected technologies, personnel exchanges, and testing and evaluation programs for near-term technological developments. The following examples are representative of the Department's technology transfer accomplishments:

1. Lawrence Berkeley Laboratory is transferring advanced zinc-nickel battery technology that it developed (with DOE support) to Acme Advanced Energy System (Tempe, Arizona), an industrial developer.
2. Sandia National Laboratory is transferring advanced zinc-air battery technology to Westinghouse Electric Corporation (Pittsburgh, Pennsylvania) for further engineering development.

3. For ease of mass production, the electric propulsion system program has modularized the advanced alternating-current-powertrain technology that it developed, and the program has installed the powertrain in the Ford Econstar electric van (Figure 2-10). Following extensive field testing in 1994, Ford could begin production in the mid-1990s.
4. AlliedSignal Corporation (Morristown, New Jersey) is applying ceramic gas turbine component technology to aircraft auxiliary power units to gain operating experience.
5. Engine manufacturers are incorporating advanced turbocharger technologies developed with Heavy Duty Transport Technology Program support into production heavy-duty diesel engines.
6. More than 83 industrial researchers and more than 66 university researchers are using experimental user facilities at the High Temperature Materials Laboratory established by DOE at Oak Ridge, Tennessee.
7. DOE sponsored the 10th International Symposium on Alcohol Fuels, held every 2 years, in Colorado Springs, Colorado, November 7 to 10, 1993.
8. DOE operates a national Hotline for public inquiries on alternative fuels. The National Alternative Fuels Hotline (1-800-423-1DOE) was started in June 1992 and received more than 1,200 calls in the first 3 months. This rate has remained consistent for the first year of operation.
9. The Alternative Fuels Data Center at the NREL collects and disseminates emissions, operational, and maintenance data on all types of alternative-fuel vehicles across the country. Data are available to both industry and the general public.

2-10. Econstar Test Bed Vehicle with a modularized 75-horsepower powertrain.

10. The DOE Alternative Fuels Utilization Program is addressing the training needs of Federal fleet operators and is working with vehicle designers, fuel suppliers, technical schools, and government agencies in developing curriculum and training programs.

INDUSTRIAL TECHNOLOGIES

Waste Materials Management

U.S. industry generates as much as 13 billion metric tons of solid waste each year—roughly 1 ton of waste each week for every American citizen. Of this, 6.9 billion metric tons are generated by the manufacturing industries, which are also the leading source of hazardous and toxic wastes. A full 80 percent of all manufacturing waste is generated by only four industries: pulp and paper, primary metals, chemicals, and petroleum refining. Recent analysis has also confirmed that industry is a major source of greenhouse gases in the United States and is responsible for more than 40 percent of carbon dioxide emissions, more than 60 percent of methane emissions, more than 60 percent of nitrous oxide emissions, roughly half of volatile organic compound (VOC) emissions, and nearly all chlorofluorocarbon (CFC) emissions.

The Environmental Protection Agency (EPA) estimated the national cost of pollution control to be \$115 billion in 1990, with industry's share at about \$73 billion. Furthermore, the EPA estimates that in the year 2000, total pollution abatement and control spending will increase to more than \$171 billion and that industry's share will be almost \$103 billion. The Office of Technology Assessment estimates that 99 percent of industry's current control costs are for end-of-pipe pollution controls that remove pollutants from the process stream *after* they have been generated. Although end-of-pipe controls are effective in meeting pollutant emission requirements, because they are expensive to construct and operate and do not add to industry's productivity or efficiency, they therefore represent an inefficient use of industry's resources.

Industrial waste streams are a costly drain on the Nation's economy and natural resources because they contain raw materials that are wasted in inefficient processes, byproducts that could be potentially recovered for reuse or sale, and waste heat that could be recovered and reused. One estimate indicates that U.S. industries produce approximately five times more waste per dollar of goods sold than Japanese companies, and more than twice as much

as German companies. This inefficient use of energy and materials contributes to the Nation's high balance-of-trade deficit.

In contrast to the relatively unproductive use of expensive pollution control equipment, waste minimization technologies can often meet or exceed environmental standards and reduce manufacturing costs with relatively modest investments. The resulting high return on investment creates an important source of funds for industrial growth and improvement. A recent study conservatively estimates that efficiency gains and cost reductions from industrial waste reduction over a 15-year period could avoid 1.3 billion tons of waste, increase gross domestic product by almost \$2 trillion, increase employment by 16 million person-years, and reduce purchases of raw materials by \$1.2 trillion.

Other opportunities exist in the use of municipal solid waste (MSW) and solar energy. The United States produces between 200 to 300 million tons (180 and 270 metric tons) of MSW annually. This garbage could supply the equivalent yearly power output of 14 large nuclear powerplants. The EPA estimates that 11 percent of this waste is separated for recycling and that another 16 percent (this number varies by year and report) is burned in waste-to-energy facilities. These two mechanisms represent a combined total recovery of about 0.5 quad (0.5 exajoule) annually, leaving a large portion of MSW's potential untapped.

Solar energy has a number of industrial applications, including industrial process heat and the detoxification of hazardous chemicals. Each year, 44,000 quads (46,200 exajoules) of solar energy—more than 500 times current energy demand—falls on the United States, but it is largely unused. Solar energy could displace up to 4.0 quads (4.2 exajoules) of thermal energy used in the industrial sector. Additionally, the ultraviolet component of sunlight, in conjunction with a catalyst, can destroy hazardous organic compounds in water. Almost one-fourth of the 20,000 water detoxification sites in the United States are located in high-insolation regions suitable for solar cleaning. There are also an estimated 730 million tons (660 million metric tons) of soil needing detoxification; more than one-third of this soil is located in high-insolation regions of the country.

Environmental considerations and environmentally conscious manufacturing are integral to the Clinton Administration's plans to increase the productivity and competitiveness of U.S. industry through technology development. In Figure 2-11, President Clinton and Al Narath, the head of Sandia National Laboratories, examine a no-clean soldering board, a collaborative effort between Sandia and the Motorola Corporation, with support

2-11. President Clinton receives the first printed wiring board manufactured by the No-clean Soldering process from Sandia National Laboratories President Al Narath. This collaborative effort between Sandia and Motorola, with support from Los Alamos, was managed by DOE's Industrial Waste Reduction Program.

from Los Alamos National Laboratory. Realizing the opportunities presented by industrial waste minimization and increased use of renewable energy sources will involve overcoming a number of technical, financial, and institutional barriers. Many long-term solutions may involve redesign of entire production processes and significant research and development. In many cases, the improved availability and accessibility of critical cost and performance data on waste management options alone will have an impact by enabling decision-makers to make better informed choices. By working cooperatively with the private sector, DOE can stimulate U.S. economic growth by promoting renewable energy technologies and technologies that minimize or utilize industrial waste.

Scope of Program

OIT conducts activities to increase industrial use of waste reduction practices and accelerate productive uses of MSW and solar energy. These activities address the three inter-

related OIT goals of increased energy efficiency and fuel flexibility, reduced energy costs, and reduced generation of industrial waste. The office directs R&D efforts in energy supply technologies toward these goals, together with the identification of barriers to wider adoption of waste reduction, waste-to-energy, and solar industrial technologies.

In pursuing its goals, OIT relies on market forces to encourage efficient choices that provide the best economic and environmentally sound use of energy. The office also seeks to remove barriers that prevent equal treatment of investments in waste reduction, waste utilization, and solar energy technologies and to remove barriers that prevent the transfer of these technologies to appropriate users. In support of these activities, OIT collaborates extensively with industry, other Federal agencies, and state and local governments. The participation of these entities not only leverages DOE resources but also increases the likelihood of accelerated market demand.

There are three major waste materials management programs within OIT: the Industrial Waste Program, the Energy From Municipal Solid Waste Program, and the Solar Industrial Program. These programs should yield important new technologies in the next 5 years (for example, improved combustion and ash emission management and pollution prevention technologies for industrial hazardous waste), in 5 to 10 years (for example, small-scale package MSW cogeneration systems and solar detoxification of groundwater), and beyond 10 years (for example, conversion of plastic waste to feedstock chemicals and anaerobic digestion of MSW). OIT will sponsor comprehensive technology and information transfer efforts to provide industry and state and local governments with technically and economically viable renewable energy supply options.

Industrial Waste

Each year, U.S. industry consumes almost 30 quads (32 exajoules) of energy in the production of goods, plus associated waste generation. Reducing the amounts of raw materials and the energy costs associated with these wastes could have a significant impact on energy conservation efforts, as well as on the growing problems associated with maintaining environmentally safe disposal practices. OIT has identified a number of opportunities for waste reduction in industrial processes, representing a potential energy savings of 3.0 quads (3.2 exajoules) annually. The actions needed to develop and implement waste reduction technologies often require a high-risk investment for many industries, and consequently they are rarely undertaken by the private sector. The objective of the Industrial

Waste Program is to help industry realize the potential for waste-related energy savings by conducting activities that focus on improved waste utilization, conversion, and reduction technologies.

Waste Utilization and Conversion

Industrial waste utilization and conversion R&D emphasizes the development of technologies for the economical processing and use of materials that are currently deposited in landfills and waterways or released in the atmosphere. During 1992 and 1993, the Industrial Waste Program continued to develop techniques in several areas.

In the metal recovery area, OIT continued work on a process to remove antimony (an undesirable component) from secondary aluminum scrap. The office also continued work on a project at Argonne National Laboratory, cost-shared with the Aluminum Recycling Association, to develop recycling processes for aluminum byproducts that are currently dumped in landfills.

In petrochemical waste recovery, research continued on processes for using rubber from waste tires. Studies have focused on achieving a high-strength bond between activated waste tire rubber and polyurethane and determining the feasibility of applications for development of potential composites. Each year, more than 250 million tires are either landfilled, dumped, or used creatively, as shown in Figure 2-12, in which scrap tire crumb rubber is used to create new products.

2-12. A new technology is being developed to create new products from scrap tires by chemically bonding the scrap tire crumb rubber with various polymers. Here, a polysulfide, treated rubber barrier membrane is used to prevent acids in storage tanks from leaking into the soil.

In the area of organic waste conversion, the Industrial Waste Program is supporting the design and construction of a 35-ton-per-day (32-metric-ton-per-day) plant to produce phenol from forest product wastes, and ultimately to produce adhesives. The program also began larger laboratory-scale experiments on processes to convert liquid potato waste from food processing into chemicals for plastics. With industry cooperation, the Purdue Research Foundation (West Lafayette, Indiana) continued the development of an immobilized cell reactor to convert cheese whey into ethanol, with a full-scale pilot plant operating at a commercial dairy in Iowa. Scale-up of the bioprocessing of carbon black off-gas into acetic acid was proceeding at the close of this report's reporting period.

Waste Reduction

DOE's activities in industrial waste reduction are aimed at developing technologies that will mitigate or eliminate waste production at the source. The implementation of new waste minimization techniques enables industry to use raw materials more efficiently and economically and reduces the substantial environmental and economic costs of waste disposal.

The Industrial Waste Program had several significant accomplishments in 1992. The successful completion of the No-Clean Soldering Project with Motorola, Inc. (Scottsdale, Arizona), and Sandia National Laboratories demonstrated the commercial feasibility of the No-Clean Soldering process. This new soldering technology for the manufacture of printed wire boards eliminates chlorofluorocarbon emissions while saving 18 trillion Btu (19 petajoules) annually once fully implemented. Another project aimed at eliminating chlorofluorocarbon emissions from solvent cleaning, which account for 20 percent of total chlorofluorocarbon annual emissions, is the Supercritical CO₂ Fluid Cleaning Project. Los Alamos National Laboratory, Sandia National Laboratories, and Pacific Northwest Laboratory, as well as many industrial partners, are participating. The Silicon Oxide Reduction Project, cost-shared with Dow Corning Corporation (Midland, Michigan) and the Canadian Government, is testing a one-sixth-scale pilot plant, using the new closed-furnace technology that will significantly reduce silicon oxide and carbon monoxide emissions during the production of silicon metal.

FMC Corporation (Pasadena, Texas) has demonstrated its methanol recovery process and has begun implementing it in several other hydrogen peroxide plants. The new process reduces hazardous waste disposal by 95 percent

and methanol purchases by 97 percent. The PPG Industries, Inc. (Allison Park, Pennsylvania), project to reclaim and reuse wastewater has been very successful. PPG is cleaning paint washwater and other process water and reusing the water for process cleaning, reducing the amount of hazardous wastewater requiring disposal by 95 percent compared with conventional painting facilities. PPG is transferring the technology to other paint companies through workshops and publications.

In addition to the above projects, the Industrial Waste Program is sponsoring more than 15 other R&D projects aimed at reducing waste and increasing energy efficiency in the industrial sector.

Energy From Municipal Solid Waste

The MSW produced annually in the United States represents an energy production and conservation potential of 3.0 quads (3.2 exajoules). The amount of MSW produced increases at approximately the same rate as the gross domestic product. About 16 percent of MSW is currently used as fuel, and an additional equivalent amount is being diverted from MSW landfills. Expanded realization of the potential benefits of MSW for energy production or conservation is currently constrained by public misconceptions about MSW processes; significant lack of pertinent environmental, cost, and energy data on waste management options; and the present state of the technology. The objective of the Energy From Municipal Solid Waste Program is to provide the data and technologies that will allow industry and the public sector to implement mutually acceptable, environmentally safe MSW use systems.

OIT's R&D activities in MSW combustion processes are building a knowledge base that will assist industry in commercializing new or improved multisector technologies for the production of steam and electricity. In 1993, Argonne National Laboratory and NREL continued a cost-shared project with industry to evaluate the thermal and environmental performance of enhanced, densified refuse-derived fuel in large-scale utility boilers.

In the area of biochemical conversion, OIT, the Environmental Protection Agency, and two tuna canneries continued cost-shared R&D in American Samoa on a biological waste-to-energy technology that will anaerobically digest tuna sludge and MSW.

Other activities at NREL in 1992 and 1993 focused on the accumulation and publication of comparative and comprehensive information on the energy-related, environmental, and economic effects of various MSW use strategies and available or proposed technologies. The objectives of

such a data compilation are to provide an information source that will enable the public to make more informed decisions about options for managing MSW and to identify serious gaps in the available data.

Additional activities will emphasize enabling technologies, such as the development of new approaches to MSW combustion gas cleanup and residue (ash) stabilization technologies.

Solar Industrial

The goal of the Solar Industrial Program is to increase the industrial use of solar energy. To achieve this goal, the program works cooperatively with suppliers and potential users to bring solar-based processes to the point where they will be successfully commercialized. A key feature of the strategy is the use of multiple entry points, targeting early applications based on a good fit in terms of geography, industrial need, economics, and environmental issues. At present, applications are being developed in process heating, soil and water detoxification, and advanced materials processing.

Process Heat

During 1993, Solar Industrial Program contacts with energy managers throughout the country found widespread interest in using solar energy in industrial process heat applications. This interest was tempered, however, by their need for information on the technical and economic capabilities of the technology. To obtain this information, OIT has embarked on a three-part program that encompasses cost-sharing in near-commercial projects.

1. *Prefeasibility studies:* During 1992 and 1993, OIT funded studies to help solar companies and potential end users develop solar heating projects. The office released another solicitation in 1993; projects were selected in late 1993, with contracts scheduled to be in place in early 1994.
2. *Cooperative programs with states:* OIT provides assistance to states that have initiated programs to increase the industrial use of solar energy. Cooperative programs under way with California, Florida, and Virginia have created additional solar projects in those states.
3. *Cooperative military programs:* The military is the largest user of energy in the United States. Discussions between OIT and the Department of Defense have led to cooperative programs with the Army

and the Air Force in 1993 to help those agencies determine the potential of solar heat to reduce their use of fossil fuels for energy applications. For example, solar heating projects were initiated at Luke Air Force Base in Glendale, Arizona; Fort Carson in Colorado Springs, Colorado; and Fort Huachuca in Sierra Vista, Alaska. In 1993, a non-operational solar system was placed back in operation to provide hot water for showers at the Luke Air Force Base gymnasium. A solar ventilation air preheating system will be built on an aircraft maintenance hangar at Fort Carson during 1994. At Fort Huachuca, solar systems will provide hot water for an indoor swimming pool.

4. *Other:* Two solar process heat concepts are being developed for export to developing nations: a solar oven and a solar ice maker. The solar oven allows villagers to cook food without gathering scarce wood. The ice maker, which is being demonstrated at a fishing village in Mexico, allows villagers to refrigerate food and medical supplies even though they have no access to electricity (Figure 2-13). Both of these will be demonstrated in the Caribbean area during 1994.

2-13. Solar-powered refrigerator makes ice for a Mexican fishing village.

Water Detoxification

Field experiments during 1992 at a Superfund site in Livermore, California, and Tyndall Air Force Base in Panama City, Florida, proved the technical feasibility of using solar energy to destroy hazardous chemicals in contaminated groundwater. During 1993, industry and the Solar

Industrial Program began cost-shared designs of solar detoxification systems with improved operation, control, and safety features. These systems will be built and used in field experiments in 1994 to demonstrate the effectiveness and economics of the process at industrial or remediation sites in 1994 and 1995.

The solar detoxification process can also be used to remove hazardous, toxic, or noxious chemicals from the air. This technology has become more important with passage of the Clean Air Act, which will prohibit many previously unregulated industrial processes. A CRADA was signed early in 1994 with International Technology Corporation to help them commercialize this technology. The process will be refined and tested at industrial facilities in 1994.

Soil Detoxification

DOE (OIT), the Environmental Protection Agency, and the Department of Defense (Army Environmental Center) formed the Triagency Project to determine the technical feasibility of using solar energy to destroy hazardous chemicals in contaminated soil. Interest in the technology centers on using the solar process to destroy hazardous chemicals while producing no hazardous products of incomplete combustion. During 1993 the Solar Industrial Program supported the Army Environmental Center in the design of a pilot-scale demonstration plant to be built at the Sierra Army Depot, California. Plant design will be completed in early 1994, followed by construction and operation by early 1995.

Advanced Materials Processing

NREL scientists, using an optical concept developed by the University of Chicago, designed and built the High Flux Solar Furnace to conduct research on new industrial applications of solar energy. Capable of producing a solar beam with the energy density found on the surface of the Sun, the furnace was first used to determine that solar energy could be used in materials processing. This work resulted in two cooperative R&D agreements during 1992: one with Coors Ceramics Company (Golden, Colorado) to develop a new, low-cost process for making silicon carbide, and one with Brush-Wellman, Inc. (Cleveland, Ohio), to develop a method for joining metal to ceramics and depositing the metal films on ceramic substrates. Laboratory experiments during 1993 proved the technical feasibility of the processes. Economic analyses during 1994 will determine whether pilot-scale demonstrations of the processes will take place at industrial sites in 1995.

Technology Implementation and Deployment

For U.S. industry to remain competitive in the coming years, it must make considerable investment in equipment and processes to improve energy efficiency and to reduce wastes. Several external factors impact the widespread use of new technologies. Favorable economic conditions are needed to stimulate investment opportunities, industry must obtain access to new and emerging environmental and energy technologies, and up-to-date information detailing the benefits associated with successfully deploying these technologies must be developed. Each of these criteria factor into how much effort is required to deploy a technology. Ultimately, however, business decisions driven by competitive forces to cut costs will determine how quickly the industrial sector will adopt new technologies and practices. To help achieve this investment climate, DOE seeks increased involvement of industry in DOE-sponsored R&D programs.

OIT supports activities aimed at identifying obstacles to the rapid adoption of energy efficiency and waste reduction technologies. The Division of Technology Implementation and Deployment plays a key role in developing strategies to overcome barriers to widespread use of industrial technologies. Many OIT deployment projects are near-term actions, such as providing energy audit assistance and demonstrating innovative equipment and technologies.

In addition to R&D activities, OIT supports an active technology transfer program to enhance communication with its industrial constituency. The office uses many mechanisms to accomplish its goals, including technical and programmatic brochures, technical factsheets, workshops and symposia, trade journal articles, educational programs, and exhibits.

For some projects that are technically developed but have not realized their commercial potential, OIT is developing accelerated deployment strategies. One such collaboration includes the Electric Power Research Institute, the University of California at Davis, the Pacific Gas and Electric Company, and the California League of Food Processors. The participants are using a traveling "membrane wagon" to test, in situ at food processing plants, the effectiveness of different membranes in separating the materials into various waste streams.

OIT's Technology Implementation and Deployment Division has the overall responsibility for working with industry to develop and implement projects that are re-

sponsive to industry needs. The division conducts outreach programs with trade associations and industry groups to multiply the effects of DOE's efforts to match technology with potential industrial users. Some of the partners that have shared in project design and implementation are the National Association of Manufacturers, the National Institute of Standards and Technology, the Environmental Protection Agency, the Departments of Commerce and Agriculture, the Electric Power Research Institute, Pacific Northwest Laboratory, and other public and private organizations.

The office annually tracks and reports on the implementation of 40 previously completed and commercialized technologies and related activities. These technologies, all developed directly by OIT, currently save an estimated 72.9 trillion Btu (76.9 quadrillion joules) per year.

The Energy Analysis and Diagnostic Center (EADC) Program, which is supported by OIT, provides a unique service to industry. The program uses tenured engineering faculty to direct the work of senior and graduate engineering students to conduct energy efficiency audits for small and medium-sized manufacturing firms.

During 1993, the EADC Program was increased from 22 competitively selected engineering schools to 26 institutions. The program completed approximately 660 energy efficiency audits, providing identified energy savings of 2.3 trillion Btu (2.4 quadrillion joules) and cost savings of \$29.7 million to small and medium-sized industrial facilities. Since 1976, the program has achieved cumulative energy efficiency savings of approximately 80 trillion Btu (84 quadrillion joules) and \$438 million, and has reduced carbon dioxide emissions by 255,000 metric tons of carbon-equivalent—at a total Federal cost of only \$26.7 million.

Historically, the energy conservation assessments conducted by EADC institutions have recommended about 4.0 billion Btu (4.2 trillion joules) of annual energy savings and \$40,000 in cost savings per plant audit. Of the energy saving measures recommended for all fuel types, about 50 percent have been implemented by the client plants. The EADCs make a second major contribution by providing direct, onsite energy management training to senior and graduate students participating in the program. Since its inception in 1976 the program has trained approximately 620 students, with 180 students currently participating in the program. Upon graduation, many of these students will be employed in energy management or related positions.

During 1993, planning was completed for combining waste assessment activity into the energy efficiency

workload of the EADCs. These activities will be a cooperative effort with the Environmental Protection Agency. Training curricula have been developed, and by the end of 1994, all experienced EADCs will have been trained to perform integrated energy and waste assessments. As each EADC makes that transition, it will be designated as an Industrial Assessment Center (IAC).

In addition to performing plant assessments, the program maintains an online computer data base at the headquarters of the Eastern Region field manager, Rutgers University (Piscataway, New Jersey). These energy efficiency data, from more than 3,000 audits, can assist in the planning and design of industrial demand-side management programs. The data base is accessible for public inquiry, and more than 300 copies of the first 10 years of these data have been distributed to universities and state energy offices.

OIT will play a significant role in a number of fundamental areas impacting U.S. industrial energy efficiency efforts for the 1990s. The office is preparing to respond to the recently passed Energy Policy Act of 1992 (Public Law 102-486), which was signed into law on October 24, 1992. The Technology Implementation and Deployment Division has the lead role and responsibility to study and develop programs attempting to achieve increased energy efficiency in industrial facilities, process-oriented industry, and industrial insulation.

One of the major efforts undertaken under the Energy Policy Act of 1992 is the development of guidelines for conducting industrial assessments on an industry-by-industry basis. Other initiatives will include the establishment of a directory of organizations offering energy efficiency assessments, technologies, and services; nonmonetary awards to utilities to recognize outstanding or innovative technology assistance programs; and an annual national meeting for interested industrial process-oriented members to stimulate and support the achievement of increased energy and waste management levels in all industrial sectors. Finally, DOE will prepare a report to Congress, evaluating the program, barriers to success, and recommendations for improvements.

In the area of industrial insulation, OIT will establish voluntary guidelines for audits in consultation with energy consumers and utilities, in hopes of identifying cost-effective and energy-efficient opportunities in insulation installation. In addition, the office will develop an education and technical assistance program to promote the use of these guidelines. Ultimately, DOE will prepare a report to Congress, evaluating the program, the effectiveness of the guidelines, and the status of the audit procedures.

BUILDING TECHNOLOGIES

Introduction

Through a national program of technology planning, R&D, testing and evaluation, and technology transfer, the Office of Building Technologies (OBT) supports private-sector efforts to increase the energy efficiency of the Nation's residential, commercial, and industrial buildings and building equipment. OBT efforts in renewable energy encourage the use of both active and passive solar systems for building energy supply options.

Scope of Program

When developing policies and establishing priorities for building technologies and energy conservation planning and management, OBT evaluates relevant national economic and energy policies and statutes, domestic and international energy demand, and Federal funding availability. The office then designs comprehensive activities, which reflect the interests and needs of end users, to transfer technological advances to the private sector and to facilitate informed decision-making by energy users.

Solar Technologies

If they are incorporated at the time of construction, existing solar energy technologies could economically displace up to 50 percent of the annual heating, cooling, and lighting energy requirements of residential and light commercial and institutional buildings in many parts of the country. Advanced technologies under development could provide an even larger share of building energy requirements. These savings translate to substantial reductions in associated emissions from the production and use of conventional energy sources.

The scope of the Solar Technologies program reflects a balanced short- and long-term R&D effort with four principal goals: (1) the cost-effective use of solar energy for space conditioning and domestic water heating; (2) reduced building cooling loads, by using natural cooling strategies and by displacing electric lighting requirements via the selective control of the daylighting resource; (3) developing cost-effective solar cooling systems, compo-

nents, and materials that will supplement or replace conventional systems; and (4) developing the necessary design tools for integrating solar technologies with other renewable energy and energy efficiency strategies.

Solar Space Heating and Water Heating

Active solar energy systems for water heating and space heating have great potential as environmentally sound ways to reduce dependence on fossil fuels. OBT works in collaboration with private industry to identify promising new materials, develop and evaluate high-performance system options, resolve existing technical and market barriers, and develop high-value niche markets.

Unglazed, transpired solar collectors are a new, low-cost, high-efficiency option for once-through air preheating applications, such as building ventilation, crop drying, and desiccant regeneration. In this concept, pioneered at NREL, outside air to be heated is drawn by a fan through holes in a dark-colored, perforated absorber sheet that is exposed to the sun. In 1992 NREL completed construction and instrumentation of an indoor Transpired Collector Test Facility, consisting of a wind tunnel and a small solar simulator. Researchers have used the facility to optimize and characterize the efficiency of the collector for a wide range of potential applications. Instrumentation of a specially designed outdoor test wall at NREL measured an efficiency of 75 percent, making this—to NREL's knowledge—the world's highest efficiency solar air heating installation in the world. NREL is also developing a computer model of airflow distribution, an early version of which was recently used by a private firm, Conservall Systems, Inc., to obtain a uniform flow design for a large installation in Germany.

DOE provides technical support for an industry-based rating and certification program sponsored by the Solar Rating and Certification Corporation (SRCC). A team composed of NREL; Colorado State University, Fort Collins; the University of Wisconsin, Madison, and the Florida Solar Energy Center, Cape Canaveral, is participating in this effort. In the past year, a major accomplishment was the promulgation and testing of the first version of SRCC-OG300, a new simulation-based rating and certification standard for solar water-heating systems. More than 40 systems have already been issued ratings, and more than 30 additional systems are in the SRCC queue. The cost for certification has been reduced from around \$10,000 to \$2,000 per system, with certifications of similar models costing an additional \$200 each. Colorado State University completed a large solar simulator facility—the only such facility in the United States today—for testing sys-

tems and solar components in 1992. Further work in 1993 focused on developing new and efficient methods of testing systems and validating system models, to complete the scientific foundation of the rating process. DOE also supports the development of a standard for certifying solar swimming pool systems (SRCC-OG400), the first draft of which was completed in 1992. A second draft, completed in January 1993, is undergoing extensive review and comment. After further revision, the standard should be in final form by the end of 1994.

A demand-side management rebate program, using solar domestic hot water systems was initiated in May 1992 by the Sacramento (California) Municipal Utility District (SMUD). This program uses the SRCC-OG300 certifications and ratings, along with inspection and quality control procedures, training of installers and SMUD inspectors, and performance-based rebates and financing (Figure 2-14). DOE provided technical support for developing performance predictions based on the SRCC-OG300 computer simulation models with SMUD inputs and Sacramento weather data. DOE and NREL are also providing technical support and hardware for field-monitoring of installed systems. SMUD's program goals are to achieve energy savings, peakload reductions, and environmental improvements while promoting the development of the solar industry and improving the cost-effectiveness and reliability of the systems for the long-term benefit of SMUD's customers. During the second 6 months of 1992, the program installed 915 systems, at an average installed price of about \$3,600. In an effort to reduce costs, SMUD issued a request for bid for an additional 200 systems, with the result that the average price was 30 percent lower, and further price decreases are anticipated as the program ex-

pands. SMUD expects that the solar systems will save some 60 to 70 percent of the annual energy use of domestic water heaters, as well as removing them from the summer peakload.

Representatives from the Edison Electric Institute, the American Public Power Association, the Solar Energy Industries Association, and DOE have formed a planning group to implement the organizations' new Utility Solar Water Heating Initiative, which has the objective of accelerating the conversion of water heating to solar energy through direct utility involvement. The objective of the first phase is to provide the information and technical assistance to establish the readiness of solar water heating as a measure for utility demand-side management. A utility workshop identified 10 information needs of critical importance to the utilities that the participating organizations will address in special studies. A meeting with solar water-heating industry representatives presented the initiative and identified opportunities for industry involvement. A stakeholders' workshop at the end of this phase will define a joint utility-industry collaborative venture, within which utilities will develop their own solar water-heating demand-side management programs. A second phase will implement the full initiative.

Solar Cooling and Dehumidification

Developments in solar cooling are proceeding along two parallel paths: low-temperature systems, using flat-plate collectors, and high-temperature systems, using advanced collectors with desiccant or absorption technology originally developed for gas-fired cooling. A research team consisting of NREL; the Florida Solar Energy Center, Cape Canaveral; Colorado State University, Fort Collins; and the University of Wisconsin, Madison, is addressing advanced designs and materials for high-temperature solar collectors having low cost, high performance, and increased durability, such as the Integrated Compound Parabolic Collector. New desiccant materials, such as polymers, are being developed and tested to allow the effective use of conventional, low-temperature solar heat for dehumidification. Solar cooling concepts and applications were explored to identify existing or emerging technologies for potential near-term deployment. Integrated solar and conventional systems with evaporative and desiccant approaches were assessed to determine their market potential in utility demand-side management and peakload shifting or reduction programs. Research activities are being concluded in 1993, and in 1994, promising advanced concepts for near-term applications will be transferred to industry for continued development.

2-14. DOE and the National Renewable Energy Laboratory support utility demand-side management programs using solar domestic hot water systems.

Passive Solar Systems

Passive solar design strategies can reduce the energy requirement of a building by 40 percent or more. Furthermore, on the average, buildings that incorporate passive solar technologies cost no more than conventional buildings to build. Analyses show that advanced passive solar technologies can potentially provide from 75 to more than 95 percent of the heating, as much as 100 percent of the cooling, and 80 percent of the perimeter daylighting requirements in a well-designed building. The goal of the OBT Passive Solar and Energy Technology Integration Program is to develop an understanding of how solar technologies interact with one another and with other energy systems in the context of the whole building and to translate that understanding into practical information that can be used by other DOE programs and by industry.

Successful application of passive strategies requires easy-to-use design tools that reflect the needs of users in the building industry. Design tools developed in cooperation with the Passive Solar Industries Council provide builders with the information they need to construct comfortable, affordable, energy-conserving buildings. In 1992 and 1993, a number of workshops were held on the use of the *Passive Solar Design Strategies: Guidelines for Home Builders* and *BuilderGuide*, a computerized version of the *Guidelines*. Workshop cosponsors include such groups as local homebuilder associations, utilities, construction companies, local chapters of the American Solar Energy Association, and state community affairs and energy offices. Total attendance at these workshops exceeds 2,000 professionals. The workshops have been approved by the American Institute of Architects for continuing education credits. The National Park Service organized three workshops for its design staff, and in February 1993 the Federal Energy Management Program offered its first *Guidelines* workshop to Federal building designers. In March 1993 the Passive Solar Industries Council held the first workshop, in Boston, Massachusetts, to teach the version developed for the remodeling industry, *Passive Solar Design Strategies: Remodeling Guidelines for Conserving Energy at Home*.

A major current thrust of the passive solar R&D effort, in collaboration with industry and the international community, is the initiation of an “exemplary” solar residential buildings program to verify that advanced passive solar, active solar, and energy efficiency technologies integrated into a building can supply at least 75 percent of the building’s space-conditioning needs at cost-effectiveness criteria relevant for the year 2000. The program provides

design assistance to cooperating design and building teams and performance measurement of the building after it is constructed by industry partners. In July 1992, NREL announced a program opportunity notice as the first step in identifying teams of designers, builders, and product manufacturers as potential participants, and it selected them in April 1993. The goal is to build five residences. The builders will construct the buildings at their own expense, OBT will provide design assistance and performance monitoring, and the Passive Solar Industries Council will develop a case study for each building to summarize the knowledge gained.

The National Park Service is collaborating in the exemplary buildings program by building two “exemplary” houses for rental to employees. One will be at Grand Canyon National Park, where a preliminary evaluation indicates a savings in heating energy of 91 percent, compared with conventional houses, by using superinsulation techniques combined with passive solar heating. A house at Yosemite National Park will be an ideal complement to that at Grand Canyon, because it has a significant summer cooling problem. An extremely low-energy house should be possible through the use of mass construction with exterior insulation and an integrated mechanical system for space heating, cooling, ventilation, and hot water. The National Park Service completed the design of these two houses, and construction began in the summer of 1993.

The International Energy Agency Solar Heating and Cooling Program includes the task of constructing low-energy buildings. Each of the 12 participating countries will build and monitor 1 or more advanced solar low-energy houses. The above-mentioned exemplary buildings on which OBT and others (such as the National Park Service) are collaborating represent the U.S. participation in the task.

Daylighting

Core Daylighting Systems

In addition to its aesthetic appeal, an atrium can provide natural illumination to otherwise dark building interiors, as well as thermal buffering from outdoor extremes (Figure 2-15). Energy performance, however, has seldom been a consideration in the design of atria in U.S. commercial buildings. OBT-sponsored work identified the general design criteria to improve the daylighting and thermal energy performance of atria. An article by DOE and LBL staff in the December 1992 issue of *Urban Land* is the first summary of information on energy-efficient atria di-

2-15. An atrium in the Comstock Center in Pittsburgh combines aesthetics and energy efficiency.

rected to building developers. The work highlighted in the article was carried out in cooperation with the other countries participating in the International Energy Agency Solar Heating and Cooling Program.

IMPLEMENTATION AND DEPLOYMENT PROGRAM

The DOE (OBT) Implementation and Deployment Program works with each research area in OBT to ensure that the knowledge, information, and processes within those areas are transferred to the appropriate users in the format and timeframe that maximize adoption and ensure that energy savings become a part of each program's research plan. Outreach activities included cofunding a major building conference sponsored by the American Council for an Energy-Efficient Economy. In 1993 the American In-

stitute of Architects/Association of Collegiate Schools of Architecture Council on Architectural Research published *Energy Tools*, a compilation with annotated descriptions of new products developed at the national laboratories that enable architects and other professionals to improve the energy performance of their buildings. "Solar Renaissance," an article in the March 1994 issue of *Home*, provides general information on currently available solar technologies and concepts appropriate for homebuilders and remodelers. In 1993, OBT completed two tabletop displays, one to show energy-efficient lighting technologies and the other a scale-model attic to demonstrate loss of R-value due to convection.

Through the technology transfer program at Oak Ridge National Laboratory and the Atlanta Support Office, in June 1992 OBT sponsored a building energy efficiency conference for the Southeast, a forum to discuss major concerns and to identify issues of particular relevance to the region. The 85 participants represented public- and investor-owned utilities; energy service companies; research laboratories; universities; and local, state, and Federal agencies. The group is planning another meeting in December 1993, in cooperation with the Tennessee Valley Authority.

Meetings with the building representatives of the support offices continued. In April 1992 there was a meeting in Berkeley, California, cohosted by Lawrence Berkeley Laboratory and the San Francisco Support Office; major topics included lighting, windows, and appliance standards. The December 1992 meeting cohosted by the Denver Support Office and NREL's Federal Energy Management Program staff concentrated on the Federal Energy Management Program analytical tools and the roles of support offices within the program. The next meeting, cohosted by Oak Ridge National Laboratory and the Atlanta Support Office, was held in May 1993; major topics included the DOE-Department of Housing and Urban Development Initiative and the Home Energy Rating System Council activities and the provisions of the Energy Policy Act of 1992 that will affect OBT.

The development of a credible, voluntary home energy rating program that is linked to mortgage finance incentives has been a significant element of the OBT Implementation and Deployment Program. A successful, uniform home energy rating system should provide an incentive that does not currently exist for the development and application of renewable and energy-efficient technologies for use in retrofitting existing residential buildings. Such a system also should stimulate improvements in energy-efficient design for new construction.

To develop a consensus on a voluntary national program, DOE, in cooperation with the Department of Housing and Urban Development, convened the National Collaborative on Home Energy Rating Systems and Mortgage Incentives for Energy Efficiency in 1991. Members of the collaborative represented 25 organizations in the housing, mortgage finance, and energy supply industries, along with state and Federal government organizations, federally chartered institutions, and public interest groups. NREL's *A National Program for Energy-Efficient Mortgages and Home Energy Rating Systems: A Blueprint for Action*, published in 1992, reports on the collaborative's findings and recommendations for creating such a program.

A coalition of financial organizations, builders, utilities, equipment manufacturers, state governments, and DOE organized a national Home Energy Rating System Council in 1992, and its initial membership meeting was held in March 1993. The council promotes energy efficiency in housing by serving as an education and research resource and by establishing a voluntary program for accrediting systems and certifying ratings, consistent with uniform guidelines to access energy-efficient mortgages and other programs. A direct outgrowth of the National Collaborative on Home Energy Rating Systems and Mortgage Incentives for Energy Efficiency, representing one of its recommendations, the development of the Home Energy Rating System Council was encouraged and sponsored by DOE and other organizations and was incorporated February 17, 1993; the initial membership meeting occurred March 15 and 16. The objective for the council is to become a self-supporting industry organization. OBT also assisted the Department of Housing and Urban Development and secondary mortgage institutions in initiating development of uniform and user-friendly energy-efficient mortgage procedures. The council has elected a 19-member board of directors and has formed 3 standing committees: technical, education, and home energy rating systems energy-efficient mortgage linkages. The council is working in partnership with DOE to draft the voluntary home energy rating system guidelines required by section 102 of the Energy Policy Act. As of June 1993, the council had 106 members.

DOE (NREL) is adapting the BESTEST (Building Energy Software Test) procedure, developed by NREL as part of the International Energy Agency Solar Heating and Cooling Program, to form the basis for certification of home energy rating system software. The procedure consists of a series of carefully specified heat transfer problems presented in the form of very simple buildings. Flow diagrams help the user interpret test results and direct the

user to diagnostic cases if the procedure indicates an error. BESTEST emphasizes different heat transfer mechanisms: each diagnostic case represents a change in a single parameter, which helps the user to identify the probable sources of a suspected error in logic and computer programming codes. The procedure has already shown itself to be a powerful quality control tool by revealing limitations in a number of leading state-of-the-art building energy simulation models in the United States and Europe. The American Society of Heating, Refrigerating and Air Conditioning Engineers is adapting BESTEST for use as a standard test method under Standard Project Committee-140.

Evaluation and Planning

OBT's evaluation and planning activities provide analytical support to the building technologies programs by compiling the needed data and evaluating program components. OBT develops data and analysis tools, which are used to identify R&D needs and technology deployment opportunities and to quantify the current and potential impacts of energy-efficient and renewable energy technologies within the building sector. The office, with help from the national laboratories, is developing and applying sector data and models in cooperation with the Energy Information Administration and the Office of Conservation and Renewable Energy's Office of Planning and Analysis. DOE uses results from these analyses to establish program priorities.

In July 1992, the American Council for an Energy Efficient Economy and the Alliance To Save Energy published *Achieving Greater Energy Efficiency in Buildings: The Role of DOE's Office of Building Technologies*, a report on a series of collaborative meetings of the Building Energy Efficiency Program Review Group. The group consists of 22 representatives from industry, utilities, universities, national laboratories, and government. DOE helped organize the group and partially sponsored its meetings. The group recommended that DOE reorient and expand its buildings program if it is to achieve its stated goals and mission. It recommended that OBT adopt a more cohesive and effective program structure, centered around three themes:

1. *Making energy efficiency happen:* Promote the implementation of, and stimulate the market for, cost-effective energy efficiency and renewable energy measures and practices.

2. *Creating new technology options:* Develop new technologies and tools through the close involvement and cooperation of the building industry.
3. *Educating energy professionals:* Place greater emphasis on education and training for energy efficiency professionals.

Stating that a sound analytical foundation is critical to the long-term success of energy efficiency efforts, the report identifies two areas in evaluation and planning where more effort should be applied: (1) data and modeling tools and (2) the planning process. The report recommends that up to 4 percent of total OBT funds should be applied to data collection, analysis, and planning (excluding analyses related establishing building and appliance standards). In May 1993, the group met again to discuss changes made by OBT in response to the report and to discuss the requirements of the Energy Policy Act on OBT programs.

TECHNICAL AND FINANCIAL ASSISTANCE

Regional Biomass Energy Program

DOE's Regional Biomass Energy Program encourages the private sector to produce biomass feedstocks and convert them to fuels through region-specific biomass energy activities. During 1992 and 1993, as in past years, the Great Lakes, Northeast, Northwest, Southeast, and Western Regional Biomass Energy Programs carried out a variety of workshops, conferences, and biomass resource assessments.

In addition, each of the five regional programs conducted competitive solicitations for cost-shared biomass energy projects of regional and national interest. These included demonstrations of fuel conversions from fossil to biomass sources, validation of biomass technology performance and economic characteristics, evaluation of environmental benefits and risks associated with the use of biofuels, and projects intended to overcome market barriers to the use of biofuels.

Committee on Renewable Energy Commerce and Trade

The Committee on Renewable Energy Commerce and Trade (CORECT), established by Public Law 98-370 in

1984, is a working group of 14 Federal agencies whose mission is to facilitate the export of U.S. renewable energy products and services. DOE's administrative management responsibility is carried out by the Office of Technical and Financial Assistance. To accomplish the committee's overall mission, the CORECT agencies, working closely with private industry, have focused their efforts on three major areas: developing new overseas markets, helping overseas customers solve problems of finance, and educating and training potential foreign customers in the use of U.S. renewable energy equipment and services.

CORECT market development activities during 1992 and 1993 focused on Latin America and the Caribbean, areas with much renewable energy potential. In Mexico, CORECT supported a range of industry efforts to facilitate the use of U.S. renewable energy technologies to help meet rural development objectives. Additional CORECT support focused on the seven countries of Central America, which constitute a market of great importance to U.S. industry.

CORECT also worked closely with the World Bank to provide information to ensure that the bank's loan portfolio includes renewable energy projects in the rapidly growing economies of the countries of the Pacific Rim and Southeast Asia. Under the committee's auspices, the U.S. Department of Commerce and the principal renewable energy industry trade association, the U.S. Export Council for Renewable Energy, held a trade conference on renewable energy use in ecotourism and food processing for the Pacific Islands in Hawaii in November 1992. This event showed decision-makers in the island nations of the South Pacific and Southeast Asia how U.S. renewable energy equipment and energy efficiency services can meet their needs.

CORECT also commenced efforts to aid in the use of renewable energy in Africa through its collaboration with industry in a new initiative, Renewable Energy for African Development.

In the area of finance, CORECT worked to address problems through its Financing Task Force, whose major activities included the Financing Energy Services for Small-Scale Energy Users (FINESSE) project, a multifaceted approach whose central aim is to help foreign customers secure capital to purchase U.S. products, and through a streamlined application system to access export financial services available from the U.S. Export-Import Bank, the Trade and Development Program, and the Overseas Private Investment Corporation.

In the area of education and training, CORECT activities during 1992 and 1993 included the support of train-

ing for participants from developing countries, particularly in PV, wind, and geothermal technologies. CORECT also sponsored numerous publications to inform potential foreign customers of the benefits of U.S. renewable equipment and services.

Technical Information Program and Conservation and Renewable Energy Inquiry and Referral Service

DOE's Technical Information Program disseminates technical information documents and technical reports covering Federal energy efficiency and renewable energy research programs. It assists researchers and technical experts in their efforts to advance the use of energy efficiency and renewable energy technologies. In 1992, the program's Technical Information Service responded to more than 4,000 inquiries from the scientific and industrial communities. The Technical Information Program produced an award-winning video on energy efficiency and renewable applications, developed a directory of Office of Energy Efficiency and Renewable Energy user facilities, and explored marketing strategies geared to specific audiences by sector.

DOE's Conservation and Renewable Energy Inquiry and Referral Service (CAREIRS) provides general information to the public on energy efficiency and renewable energy technologies and processes. CAREIRS also publishes and disseminates materials on frequently requested energy issues. In 1992 CAREIRS responded to more than 42,000 telephone and written requests for information on energy efficiency and renewable energy.

National Appropriate Technology Assistance Service

Congress created the National Appropriate Technology Assistance Service (NATAS) to assist the public in implementing conservation and renewable energy techniques and technologies and to offer commercialization and business assistance to energy-related businesses and inventors with energy-related products. NATAS provides tailored information and engineering, scientific, and technical aid to anyone in the United States who needs help in implementing an energy project. In addition, through business

planning, development, and financial analysis services, NATAS helps inventors and entrepreneurs to develop and market products that use renewable energy or that conserve energy. NATAS personnel work closely with Federal, state, and local programs to coordinate technical assistance activities.

Since its creation, NATAS has responded directly to nearly 70,000 requests for assistance and has placed informative technical and how-to articles in newspapers and magazines reaching millions of readers. In 1992, the program responded to approximately 6,000 requests for technical assistance and more than 800 requests for business development assistance. In addition, it placed technical articles in magazines with a combined circulation of 3.5 million readers. NATAS has also assisted energy-related businesses that are looking for international development opportunities.

Commercialization and Demonstration Program: Joint Ventures

The Energy Policy Act of 1992 (Public Law 102-486) amended the Renewable Energy and Energy Efficiency Technology Competitiveness Act of 1989 (Public Law 101-218), by expanding the scope of the planned Joint Ventures program to further the commercialization of renewable energy and energy efficiency technologies and products. The goal of DOE's commercialization and demonstration activities will be to assist viable technologies already developed and at the very end of the R&D spectrum that merely need a final boost to achieve commercialization. The Joint Ventures Advisory Committee met twice during 1992 and developed additional guidelines for the implementation of the program. While awaiting the availability of funding, DOE has established the structure of the program, determined project selection criteria, and prepared a draft project solicitation.

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CHAPTER 3

FOSSIL ENERGY

INTRODUCTION

The President, shortly after taking office in January 1993, reaffirmed that natural gas, one of the cleanest fossil fuels, would receive priority attention in the energy programs of his Administration. In April 1993, the Secretary responded to the President's direction by proposing a 1994 budget that would push departmentwide funding for natural gas technologies over the \$200 million mark, nearly 40 percent more than 1993 funding.

In carrying out the President's commitment, DOE's Office of Fossil Energy, in a joint effort with the Office of Energy Efficiency and Renewable Energy and industry, accelerated its program to develop advanced, 21st-century gas-fired turbine systems. As confidence in natural gas as an abundant domestic energy resource has grown, the utility and industrial sectors have begun looking increasingly to the gas-fired combustion turbine to supply future power needs. DOE's new program to develop high-efficiency gas turbines could offer a quantum leap in efficiency and environmental performance compared to the commercial turbines expected in the 1990s. DOE set a target of the year 2000 to have the first commercial demonstration units in operation.

In 1993, the Office of Fossil Energy also shifted efforts to develop fuel cells into its natural gas program. The move reflected recognition within the power industry that natural gas likely will be the first fuel used for utility-based fuel cell systems entering the commercial market this decade.

While new efforts were under way to encourage greater use of natural gas, two other, previously begun Office of

Fossil Energy partnership programs with industry reached major milestones in 1992–1993. In the Clean Coal Technology Program, DOE completed its selections of industry-proposed demonstration projects for the originally planned, five-round joint Government-industry program. The Department's announcement of fifth-round projects on May 4, 1993, brought to 46 the number of projects either active or completed in the program. Greater-than-anticipated private-sector cost sharing, including more than \$1.6 billion in private financing for fifth-round projects, pushed the total value of the Clean Coal Technology Program to more than \$6.8 billion—well above the original \$5 billion target set when the program was created in 1986.

In a second major partnership effort—this one with the Nation's oil industry—DOE moved from early planning efforts into the selection and funding of actual field demonstration projects under the Reservoir Class Field Program. In 1992–1993, the Department announced selections of industry-proposed projects to receive Federal financial support. Each set of projects focuses on a specific geologic class of domestic reservoirs in danger of being abandoned this decade. By providing Federal assistance, DOE hopes to encourage operators to try new or underused technologies that could prolong the economic life of these fields.

While these new initiatives were under way, DOE also began refocusing its coal research and development program to concentrate increasingly on the utility power generation market—the domestic energy sector in which coal is likely to remain the dominant fuel. The Department also increased its emphasis on technology transfer, using, for example, a cooperative research and development agree-

ment—a congressionally authorized technology transfer arrangement to share expertise and facilities at its Energy Technology Centers and national laboratories with private-sector entrepreneurs. The Pittsburgh Energy Technology Center researchers pictured in Figure 3-1 are displaying the Federal Laboratory Consortium's Award for Excellence in Technology Transfer for 1993. They developed a patented nitrogen oxide control method subsequently licensed to a private company.

In addition to its efforts to develop new fossil fuel technologies, the Office of Fossil Energy continued to fill the Strategic Petroleum Reserve (SPR)—the Nation's emergency crude oil stockpile. Simultaneously, it began a new effort, at the direction of the Secretary, to seek alternative means of financing future fill and possible expansion of SPR, focusing on options that could reduce Federal budget outlays in line with the President's deficit reduction goals.

Much of the crude oil added to SPR in 1992-1993 came from the Government-owned Naval Petroleum Reserve No. 1 at Elk Hills, California, one of the Nation's largest oil fields. DOE opted to transfer Elk Hills oil to SPR when low oil prices in the California market prevented sales of crude oil from the field from meeting congressionally required price tests. In 1993, with costs of producing oil from the Elk Hills increasing and market conditions changing, DOE undertook a new effort to examine alternative management approaches that could lead to more efficient operations at the Naval Petroleum and Oil Shale Reserves.

3-1. Researchers from the Pittsburgh Energy Technology Center receive the Federal Laboratory Consortium's Award for Excellence in Technology Transfer for 1993. The researchers developed a patented NO_x control method that was subsequently licensed to a private company.

Included in the study options was the potential to create a new Government corporation to manage the fields, similar to that established for the marketing of enriched uranium for nuclear powerplants. The study became a major part of the Department's response to the President's call to "reinvent government."

CLEAN COAL TECHNOLOGY PROGRAM

The Clean Coal Technology Program, established in 1986 to help reduce acid rain, completed the fifth of its planned five rounds of competition in 1993, with the newest projects meeting a much broader set of post-year-2000 environmental and energy objectives.

On May 4, 1993, DOE selected 5 projects, bringing to 46 the number of active demonstration ventures in the Clean Coal Technology Program. In addition to addressing acid rain concerns, the five projects will show how greenhouse gases, such as carbon dioxide, can be reduced by boosting the efficiency of the coal-to-energy process. The five projects are as follows:

1. Camden Clean Energy Project, a 480-megawatt advanced integrated gasification combined-cycle plant proposed by Duke Energy Corporation (Charlotte, North Carolina), General Electric Company (Schenectady, New York), and Air Products and Chemicals, Inc. (Allentown, Pennsylvania), for Camden, New Jersey
2. Calvert City Advanced Energy Project, a 95-megawatt advanced pressurized circulating fluidized-bed powerplant proposed by Air Products and Chemicals, Inc., for Calvert City, Kentucky
3. Clean Power from Integrated COREX (CPICOR), a demonstration proposed by Centerior Energy Corporation (Independence, Ohio) for LTV Steel Company's Cleveland, Ohio, works, which would combine a hot-iron production process for the steel industry with an electricity cogeneration technology
4. Warren Station Externally Fueled Combined Cycle Demonstration, a project proposed by the Pennsylvania Electric Company to repower its Warren, Pennsylvania, station with an innovative power generating system that would use a ceramic heat exchanger to protect the gas turbine from hot, corrosive coal gases
5. Demonstration of Clean Coal Diesel Technology, a project proposed by Easton Utilities (Easton, Mary-

land), Cooper Bessemer (Mt. Vernon, Ohio), and Arthur D. Little, Inc. (Cambridge, Massachusetts), that would add 14 megawatts of power to the municipal power facility at Easton, Maryland, by installing a coal-fired diesel engine

The five project sponsors collectively offered the most private cost sharing ever proposed by winning projects in a Clean Coal Technology Program solicitation. The companies proposed to more than match DOE's \$568 million with more than \$1.6 billion of their own funds. Overall, in the five rounds of the Clean Coal Technology Program, higher-than-expected private funding turned a \$5 billion program envisioned in 1986 into a \$6.8 billion program.

When the Department established the Clean Coal Technology Program, the U.S. and Canadian Joint Envoys on Acid Rain gave the program a clear mandate: "If the menu of control options were expanded, and if the new options were significantly cheaper, yet highly efficient, it would be easier to formulate an acid rain control plan that would have broader public appeal." (*Report of the U.S.-Canadian Joint Envoys on Acid Rain, 1985*)

Largely from projects selected in the first three rounds of competition, the program has met that mandate. By mid-1993, 23 of the earlier projects were generating data. Most were demonstrating advanced technologies that can reduce sulfur dioxide (SO₂) and nitrogen oxide (NO_x) emissions from existing plants.

With a broad range of these retrofit technologies in operation, DOE shifted the focus of the Clean Coal Technology Program's final two rounds to 21st-century goals: to improve overall plant efficiencies, to make solid waste environmentally benign, and to meet the post-year-2000 emission limits imposed by the Clean Air Act Amendments of 1990.

The growing maturity of the Clean Coal Technology Program may return international dividends. Several advanced pollution control systems, in particular, attracted potential purchasers from overseas. Delegations from Thailand and China, both of which expect to rely increasingly on coal for economic expansion, viewed many examples of innovative technologies during trips to the United States in 1992-1993.

Newly Negotiated Clean Coal Technology Projects

In 1992-1993, DOE completed negotiations on all but one of the projects from the Clean Coal Technology Program's

fourth-round competition, as well as the final project from the third round.

Air Products and Chemicals Methanol Synthesis

In August 1992, DOE announced an agreement with Air Products and Chemicals, Inc., for a \$213.7 million effort to demonstrate an advanced coal-to-methanol process at the Coolwater gasification combined-cycle plant in Daggett, California. Dakota Gasification, Inc., had originally proposed the third-round project for the Great Plains Coal Gasification Plant in Beulah, North Dakota.) After a mandatory congressional review period, DOE signed the agreement on October 16, 1992.

Sierra Pacific Power Company's Piñon Pine Integrated Gasification Combined-Cycle Power Project

In June 1992, DOE completed negotiations with the Sierra Pacific Power Company (Reno, Nevada) for the Piñon Pine project—an 80-megawatt coal gasification combined-cycle powerplant at the Tracy station near Reno. The \$270 million fourth-round project will use second-generation gasification combined-cycle technology developed by the M.W. Kellogg Company (Houston, Texas). DOE and Sierra Pacific signed the cooperative agreement on July 31, 1992.

Wabash River Coal Gasification Repowering Project

DOE completed negotiations for this fourth-round gasification combined-cycle power project also in June 1992 and signed the agreement in July 1992. The Wabash River Coal Gasification Repowering Project, a joint venture between PSI Energy, Inc. (Plainfield, Indiana), and Destec Energy, Inc. (Houston, Texas), will modernize a 29-year-old steam turbine generator at an Indiana powerplant with the Nation's largest single-train coal gasification power system. Reconstruction of the turbine generator began in summer 1993. The \$396 million project will double the plant's power output and help it comply with the Clean Air Act Amendments of 1990. Construction began in 1993.

Tennessee Valley Authority Micronized Coal Reburning

The Tennessee Valley Authority will demonstrate an innovative approach to using a technique called reburning

to reduce nitrogen oxides. In reburning, a supplemental fuel is used to destroy nitrogen oxides within a boiler. The Tennessee Valley Authority will use micronized coal (coal ground to extremely fine, "micron" sizes) as the reburn fuel in the \$7.3 million fourth-round project at the Shawnee station near Paducah, Kentucky.

TAMCO Power Partners Tom's Creek Integrated Gasification Combined-Cycle Project

This gasification combined-cycle project from the fourth round will demonstrate the U-Gas coal gasification technology developed in the 1970s in DOE's research and development program. Under a \$196 million agreement announced in September 1992, TAMCO Power Partners, a partnership between units of Tampella Power Corporation (Williamsport, Pennsylvania) and Coastal Power Production Company (Roanoke, Virginia), would build and operate an advanced power and steam cogeneration system at the Tom's Creek coal mine near Coeburn, Virginia.

New York State Electric and Gas Milliken Clean Coal Project

In September 1992, DOE announced a \$159 million agreement with New York State Electric and Gas (Binghamton, New York). Under the agreement, the utility will refurbish the Milliken station in Lansing, New York, with three advanced pollution control technologies: a low-energy-consuming scrubbing technology that can capture up to 98 percent of SO₂ emissions, the world's first large-scale utility demonstration of the NO_xOUT technique with high-sulfur coals, and a high-efficiency air heater system. Construction of advanced pollution control equipment at the Milliken station began in summer 1993.

Custom Coals International Self-Scrubbing Coal Project

In an \$81.7 million project agreement reached in September 1992, Custom Coals International (Pittsburgh, Pennsylvania) will demonstrate several advanced coal-cleaning techniques. One, called the Micro-Mag process, was developed by DOE's Pittsburgh Energy Technology Center. The project will involve the construction and operation of an advanced coal preparation plant at the site of an existing coal-cleaning plant near Stoystown, Pennsylvania. Cleaned coals will be tested in commercially operating utility boilers in Indiana, Ohio, and Pennsylvania.

ThermoChem Pulsed Combustion Demonstration

In the final project from the fourth round to be negotiated in 1992, DOE reached agreement with ThermoChem, Inc. (Columbia, Maryland), to demonstrate a unique coal gasification process. The technology derives heat by burning cleaned product gases in "pulsed" combustion tubes within a fluidized bed. The 300-ton-per-day (270-metric-ton-per-day) unit will be built at the Caballo Rojo Inc. mine near Gillette, Wyoming. An important advantage of the combustor-gasifier is that it can use a full range of solid and gaseous products as fuel, including wastewater sludge, refuse-derived fuel, wastes from paper mills, lignite, and mild gasification char. DOE agreed to move the \$37.3 million project from its original site, a paper plant in Springfield, Oregon.

Remaining Fourth-Round Projects

In 1992, DOE did not complete negotiations for two of the nine projects selected in the fourth round. In September 1992, Cordero Mining Company (Gillette, Wyoming) withdrew its proposal after concluding that the proposed advanced coal-drying plant would be unlikely to operate profitably in the near future.

In August 1993, Union Carbide Chemicals and Plastics Company, Inc. (Danbury, Connecticut), withdrew its proposed demonstration of the CANSOLV process at an aluminum manufacturing plant when it could not find an equity partner for the project. Previously, Union Carbide had decided that it could not finance the project alone and that it needed to attract an equity partner to successfully commercialize the technology.

Rounds 1 Through 3: Highlights

Projects selected in the first three rounds of the Clean Coal Technology Program achieved significant milestones in 1992–1993, including those described in the following sections.

Pure Air Advanced Flue Gas Desulfurization Process

On June 2, 1992, the Bailly station, owned by Northern Indiana Public Service Company (Hammond, Indiana) and

3-2. A view of Northern Indiana Public Services' Bailly station on the shores of Lake Michigan. Through the Clean Coal Technology Program, this plant became the first in the Nation to meet SO_2 standards that will be imposed by the Clean Air Act Amendments of 1990. The plant was named 1993 Power Plant of the Year by Power magazine.

viewed in Figure 3-2, became the first U.S. powerplant to meet the upcoming SO_2 standards that will be imposed by the Clean Air Act Amendments of 1990. The plant employed an advanced flue gas scrubber installed under the Clean Coal Technology Program. In a novel business arrangement, the innovative scrubbing system is owned and operated by Pure Air, a general partnership between Air Products and Chemicals, Inc., and Mitsubishi Heavy Industries America, Inc. (New York, New York). The scrubbing system achieved its performance expectations during 1992 and 1993, consistently reducing SO_2 emissions by more than 95 percent and producing byproduct gypsum with average purities of 96 to 97 percent.

In January 1993, the project received the National Society of Professional Engineers' Outstanding Achievement Award for 1992. In April, McGraw-Hill's *Power* magazine named the Bailly station one of its "Power Plants of the Year" for 1992.

American Electric Power's Tidd Pressurized Fluidized-Bed Combustion Plant

In July 1992, American Electric Power's refurbished 70-megawatt Tidd powerplant at Brilliant, Ohio, the Nation's first pressurized fluidized-bed combustion plant, achieved its initial environmental and technical performance goals by completing 720 hours of continuous operation. By early 1993, the plant had accumulated nearly 3,500 hours of coal-burning operation, including runs of 102 and 360 hours in which advanced ceramic particulate filters were tested using a hot-gas slipstream from the combustion unit.

Passamaquoddy Tribe Recovery Scrubber Project

The Passamaquoddy Tribe's clean coal technology project at a cement plant in Thomaston, Maine, continued to dem-

onstrate an advanced flue gas scrubbing system that is solving two pollution problems simultaneously. The innovative technique, developed by the tribe to dispose of its waste kiln dust, uses the waste to clean SO_2 from the plant's flue gases. The only byproducts are potassium sulfate, which can be used for fertilizer, and distilled water. The innovative scrubbing system met the project goal of 90- to 95-percent SO_2 emission reduction, with a maximum reduction of 98 percent. In 1993, it became a permanent part of the operating cement plant.

Rosebud Syncoal Project

In March 1992, DOE announced that a newly built, grassroots clean coal technology plant in Montana had begun operations ahead of its planned schedule. Rosebud Syncoal Partnership, a joint effort between Western Energy Company (Billings, Montana) and the NRG Group of Minnesota, built the plant. The plant is demonstrating an advanced thermal drying and coal cleaning process that can reduce the moisture and sulfur content of low-rank, subbituminous, and lignite coals. By December 1992, shipments of approximately 5,000 tons (4,500 metric tons) of SynCoal product had been delivered to Montana Power Company for trial burns.

ENCOAL Mild Gasification Project

In July 1992, DOE gave the go-ahead to the ENCOAL Corporation (Houston, Texas) to begin full-scale operations of its demonstration plant near Gillette, Wyoming. Under the mild gasification project, the plant is converting low-rank coals into two clean fuels, one solid and one liquid. ENCOAL secured two buyers for the products: a utility that will buy the solid fuel for its powerplants, and a company that will buy up to 135,000 barrels (18,500 metric tons) of oil equivalent liquid fuels per year to market to industries. By mid-1993, 14 test runs had been completed, representing about 1,550 hours of operation on coal. ENCOAL shipped the first coal-derived liquid to an industrial customer in October 1992.

SNOX and SO_x - NO_x -Rox-Box Projects

In July 1992, DOE announced the startup of two innovative clean coal technologies designed to capture multiple pollutants from coal-burning powerplants. In one, ABB Environmental Services (Birmingham, Alabama) began testing the novel SNOX process at Ohio Edison's Niles station in eastern Ohio. SNOX is a postcombustion cleanup

system that removes both SO_2 and NO_x while producing a marketable sulfuric acid byproduct. From early test data, the system showed that it could capture 96 percent of the sulfur pollutants and 94 percent of the NO_x emissions.

The second project is taking place at Ohio Edison's Burger plant in Dilles Bottom, Ohio. Following a 7-month construction period, Babcock and Wilcox Company (Alliance, Ohio) began tests of the SO_x - NO_x -Rox-Box (SNRB) process in May 1992. Like the SNOX process, SNRB offers a way to capture SO_2 , NO_x , and particulates. A difference is that, using the SNRB technology, all pollutants are captured within a single high-temperature baghouse, saving space and cost. The process exceeded its goals with SO_2 reductions of up to 85 percent and NO_x reductions of more than 90 percent. Particulate emissions have been consistently less than 0.03 pound per million British thermal units (Btu) (13 grams per gigajoule).

Public Service of Colorado

In August 1992, full-scale tests of several retrofit technologies to reduce sulfur and nitrogen emissions (low- NO_x burners, overfire air, and in-furnace urea injection for NO_x control, and sorbent injection and flue gas humidification for SO_2 control) began at a powerplant in Denver, Colorado. These represent the first low- NO_x combustion tests on a top-fired boiler, a relatively uncommon but high NO_x -emitting boiler for which currently there is no commercial control technology.

The low- NO_x combustion system was able to achieve about a 65-percent reduction in nitrogen oxides. In January 1993, to achieve further reductions in pollutants, plant engineers began testing a urea injection system in the coal-burning furnace.

Southern Company Services CT-121 Advanced Scrubber

In October 1992, DOE announced the start of full operations of another advanced retrofit pollution control system. Southern Company Services (Birmingham, Alabama) began operating a second-generation flue gas scrubbing system constructed of economical fiberglass. The tests are being conducted at Georgia Power Company's Plant Yates near Newnan, Georgia, outside Atlanta. Preliminary results indicate 93- to 98-percent SO_2 removal, exceeding the objective of 90 percent. Figure 3-3 shows the CT-121 Advanced Scrubber.

3-3. Visitors take a close look at the CT-121 Advanced Scrubber now operating at Georgia Power's Plant Yates outside Atlanta. The system began operating in October 1992. SO_2 capture rates have ranged from 93 to 98 percent, well exceeding the project objectives.

AirPol Gas Suspension Absorption Project

In October 1992, AirPol, Inc. (Teterboro, New Jersey), began demonstrating its gas suspension absorption process at the Tennessee Valley Authority's National Center for Emissions Research (Paducah, Kentucky). The technology promises to combine the economic benefits of spray dryers, while attaining SO_2 removal levels close to those of wet scrubbing processes. Early tests conducted to test the system's limits indicate that SO_2 emissions could be reduced by as much as 99 percent.

EER Gas Reburning with Low-Nitrogen Oxide Burners

In December 1992, DOE announced the start of tests of a clean coal technology project in Denver, Colorado. The project, sponsored by EER, Inc. (Irvine, California), is demonstrating that reburning natural gas in a coal-fired boiler, combined with low- NO_x burners, can reduce NO_x emissions as much as more expensive postcombustion controls. Early analysis showed NO_x reductions of up to 70 percent at full load. Long-term operations began in February 1993.

Project Changes

In 1992, DOE agreed to major changes in two clean coal technology projects already under cooperative agreements. In the first, DOE agreed to keep active one of the largest projects in the program: American Electric Power's proposed 340-megawatt advanced pressurized fluidized-bed combustion project. On January 20, 1992, DOE approved American Electric Power's request to delay construction of the plant until later in the decade because of reduced demand for electricity. American Electric Power, in turn, agreed to build the advanced demonstration plant as the next new baseload power station serving the area served by its subsidiary, the Appalachian Power Company.

In the second major project change, DOE agreed to reassign a project originally sponsored by the City of Tallahassee, Florida, to the York County Energy Partners, L.P., a subsidiary of Air Products and Chemicals, Inc. The new sponsor announced that it would move the project to an industrial site in York County, Pennsylvania, where the advanced power-generating plant would also operate as a steam cogeneration facility.

Advanced Coal Power Systems Research and Development

In 1992-1993, DOE elevated the development of high-performance, environmentally clean electric power generation systems to highest priority in research and development on coal. This emphasis reflects coal's current role in supplying nearly 56 percent of the Nation's electric power and projections that it will continue to be the dominant fuel for electricity generation in the United States and in many other countries well into the 21st century.

During 1992, DOE identified four strategic objectives for its coal-based electric power-generating program:

1. By the year 2000, achieve 42-percent efficiencies (compared with current U.S. technology levels of 33 to 35 percent) while reducing SO_2 , NO_x , and particulate emissions to no more than one-third of the emission levels required by the Clean Air Act's New Source Performance Standards (NSPS).
2. By 2005, achieve 47-percent efficiencies while reducing SO_2 , NO_x , and particulates to no more than one-fourth of the NSPS levels at costs lower than current pulverized-coal combustion technology.
3. By 2010, achieve 55-percent efficiencies while reducing SO_2 , NO_x , and particulates to no more than one-tenth of the NSPS levels. In addition, toxic emissions must be able to meet yet-to-be-defined levels; solid waste must be nontoxic and at least partially marketable; and the cost of electricity must be 10 to 20 percent less than that of current systems.
4. By 2015, achieve 60-percent efficiencies while continuing to meet year-2010 environmental and economic performance goals.

Advanced Combustion Power Systems

DOE's coal combustion programs include second-generation pressurized fluidized-bed combustion, the low-emission boiler system concept, and a distinctly different approach known as the indirectly fired cycle.

Pressurized Fluidized-Bed Combustion

Pressurized fluidized-bed technology is an inherently clean combustion process in which sulfur and nitrogen pollutants are captured or reduced inside the boiler. Largely because of several projects in the Clean Coal Technology Program, the commercial readiness of the technology is accelerating. In 1992–1993, DOE sponsored research and development to further improve the technology's efficiency and potentially lower the cost of electricity.

In January 1993, Foster-Wheeler Development Corporation, working under DOE contract, completed shakedown testing of its Circulating Pressurized Fluidized Bed Combustor pilot plant in Livingston, New Jersey. In this second-generation system, coal is first partially gasified in a carbonizer to produce a low-Btu-content (low-heat-content) fuel gas and a solid char. The gas is then burned in a "topping" combustor to produce energy for a gas turbine, while the char is burned in a pressurized fluidized-

bed combustor to produce steam for a steam generator, producing another source of electricity. This combination is projected to increase overall efficiency of the power-generating process to levels approaching 49 percent. The result is fewer greenhouse gas emissions and potentially lower cost electricity. Test runs of individual components and subsystems began in April 1993.

In July 1993, a team of DOE contractors led by Southern Company Services broke ground on the Power Systems Development Facility in Wilsonville, Alabama. This multipurpose, modular facility will be the test site for scaleup of the advanced pressurized fluidized-bed technology, as well as for other improved power-generating systems. It will also serve as the test bed for new subsystems, such as advanced hot-gas cleanup technologies. In May 1993, Southern Company Services and DOE announced the selection of three companies to supply the first of these subsystems. Combustion Power Company (Menlo Park, California), Westinghouse Electric Corporation (Pittsburgh, Pennsylvania), and Industrial Filter and Pump Manufacturing Company (Cicero, Illinois) will fabricate advanced particulate control devices for testing at the Wilsonville facility.

Advanced particulate control technology was also the objective of a research and development project at the Tidd Clean Coal Technology Project in Brilliant, Ohio. In October 1992, plant operators began diverting a slipstream of combustion gases from the pressurized fluidized-bed boiler through an advanced candle-shaped, ceramic filtration system designed by Westinghouse Electric. The unit tested at the Tidd plant was the largest of its kind ever built, and preliminary results showed that it could meet its goal of removing more than 99.9 percent of the tiny ash particles in the coal gas. Work is also under way at the Tidd facility to evaluate a granular bed filter that can control certain hazardous air pollutants in addition to capturing particulates.

Low-Emission Boiler Systems

Another project in DOE's coal combustion program is the development of a low-emission boiler system. In this approach, several advanced pollutant removal techniques would be integrated into the design of a pulverized-coal-fired supercritical boiler, rather than being added as retrofits as the practice is today.

In early 1992, DOE selected three industrial teams to begin a 2-year effort to analyze candidate technologies and system components, prepare a research-and-development test plan, and develop a preliminary design for a commercial-scale plant. The teams are led by ABB

Combustion Engineering (Windsor, Connecticut), Babcock and Wilcox, and Riley Stoker Corporation (Worcester, Massachusetts). It is expected that the two teams with the best designs will proceed to engineering development and testing and design of a proof-of-concept plant in phases II and III, respectively. Finally, one team will be chosen to build and operate the proof-of-concept facility in phase IV. A commercial basis for the low-emission boiler system should be available before the year 2000.

Indirectly Fired Cycles

This advanced combustion concept is a distinctly different approach from using coal to generate electricity. The technology generates power from a coal-fueled heat source without the combustion gases coming into contact with the gas turbine. Through advanced furnace design, contact of coal combustion products with high-temperature surfaces that transfer heat to the turbine air is minimized or even eliminated—significantly reducing the dependence on corrosion-resistant ceramic materials for these heat-transfer surfaces. When a steam cycle is added, an indirectly fired system is projected to achieve efficiencies approaching 50 percent for first-generation systems and perhaps as high as 55 percent for more advanced versions.

A 15-member industry consortium led by Hague International (Portland, Maine) is studying a relatively near-term approach to the indirectly fired cycle, based on a high-pressure, ceramic heat exchanger. This approach utilizes a shell and tube heat exchanger with ceramic tubes and other ceramic components. Hague is building a test facility in Kennebunk, Maine, and plans to begin tests of the indirect cycle in fall 1993. Through the Clean Coal Technology Program, the Department selected Hague to demonstrate an indirect-cycle technology at Pennsylvania Electric Company's Warren, Pennsylvania, station.

Two industry teams selected in late 1991 to develop high-performance power systems continued their work in 1992. The first team, led by Foster Wheeler Development Corporation (Livingston, New Jersey) includes Bechtel Corporation (Houston, Texas), General Electric, Research-Cottrell (Research Triangle Park, North Carolina), TRW Inc. (Redondo Beach, California), and Allied-Signal (Morristown, New Jersey). The second team, led by United Technologies Research Center (Orlando, Florida), includes UTC Turbo Power and Marine Division (Orlando, Florida), Bechtel Corporation, PSI Technology Company Reaction Engineering International (Indianapolis, Indiana) the University of North Dakota Energy and Environmental Research Center (Grand Forks, North Dakota), and Oak Ridge National Laboratory. Both teams are conducting initial

research to develop promising furnace designs for such a system. In late 1993, DOE will issue a competitive solicitation to move into the next phase: engineering development and testing.

Successful development of any indirectly fired cycle system relies on effective high-temperature heat transfer between the products of coal combustion and an air stream used within a Brayton cycle. A key technical issue is the ability of materials to maintain their integrity under high-temperature, corrosive conditions. Beginning in 1992, Oak Ridge National Laboratory began screening candidate materials for use in indirectly fired cycles.

In another supporting effort, Advanced Fuel Research (East Hartford, Connecticut) is studying a novel approach to the design of a high-temperature advanced furnace. In this approach, the furnace relies on radiative heat transfer to heat the turbine air. A clean gas stream, such as that produced by combusting natural gas, sweeps across the air-heater surfaces to prevent deposition and corrosion that products of coal combustion can cause. Results of two-dimensional modeling and some experimental work seem to confirm that such a design would be successful in preventing damage to the air-heater surfaces.

Magnetohydrodynamics

DOE's multiyear program to prove the technical viability of the coal-fired magnetohydrodynamics (MHD) electric power generation technology was completed in 1993.

DOE's Component Development and Integration Facility in Butte, Montana, completed more than 600 hours of test operations. The Department is using this facility to test a prototype MHD topping cycle system. The first test of proof-of-concept hardware took place in October 1992 and ran through 1993. The tests of the high-temperature, pressurized coal combustor, nozzle, and channel were the first to use equipment designed and built for long-duration operations.

The second key MHD subsystem is the bottoming cycle, or heat recovery system, in which a conventional steam-driven turbine is used to boost power-generating efficiencies to well above 50 percent. Tests of the bottoming cycle took place at the University of Tennessee's Coal-Fired Flow Facility in Tullahoma, Tennessee. Test series of 2,000 hours using Illinois No. 6 coal and 1,500 hours using Montana Rosebud coal were completed in 1993.

In summer 1992, the program reached a third milestone in Capistrano, California, where TRW verified the effectiveness of a series of chemical processing steps for regenerating the potassium needed for the MHD process.

Gasification Combined-Cycle Power Systems

Integrated gasification combined-cycle powerplants offer extremely clean and efficient electricity generation from coal. Advanced gas stream cleanup systems can reduce sulfur impurities by more than 99.9 percent. Control systems can reduce release of nitrogen oxides by more than 90 percent. Solid wastes are environmentally benign and easily handled, and the system's high thermal efficiencies can lower carbon dioxide emissions by 20 percent or more.

DOE's Clean Coal Technology Program will demonstrate several coal gasification combined-cycle projects. The companion research and development program is focusing on improving key components of the gasification power train that have a major impact on system costs, efficiency, and environmental performance.

Gasification Product Improvement Facility

Because today's commercial gasifiers originally were developed for a variety of purposes, a major focus of DOE's Fossil Energy Research Program is to develop an advanced gasifier optimized for power generation.

In September 1992, DOE signed a cost-shared agreement with CRS Sitrine Engineers, Inc. (Greenville, South Carolina), to design and fabricate an innovative, air-blown pressurized, dry-bottom gasifier and associated equipment for a new DOE test facility at the Fort Martin powerplant near Morgantown, West Virginia. This advanced, 5-foot- (1.5-meter-) diameter hybrid gasifier is being designed specifically for integrated gasification combined-cycle power systems and will focus on key issues such as use of coal fines, handling agglomerating coals, and increasing throughput. The facility could later become a test-bed for advanced gas stream cleanup systems.

Hot Gas Cleanup Systems

A key component of the 21st-century gasification-based powerplant will be the downstream gas cleanup system. Integrated between the gasifier and the gas turbine (or the fuel cell stacks in later configurations), this system will be a major factor in determining a powerplant's overall efficiency and cost as well as its environmental performance.

In 1992, DOE-sponsored work on advanced gas cleanup systems continued at General Electric's Performance Evaluation Facility in Schenectady, New York. This facility is made up of a small pressurized, air-blown fixed-

bed gasifier; gas-cleaning equipment; and a gas turbine simulator. Testing in 1992–1993 focused on a moving-bed cleanup design developed by General Electric that is potentially more effective than earlier, fixed-bed systems. DOE evaluated a zinc titanate sorbent for hydrogen sulfide removal, which is now a candidate for use at two of the gasification combined-cycle projects in the Clean Coal Technology Program.

In another gas cleanup project, Research Triangle Institute (Research Triangle Park, North Carolina) designed and built a bench-scale facility for testing its Direct Sulfur Recovery Process. The project showed that the two-stage reactor system is capable of converting up to 99 percent of the sulfur impurities in the coal gas to elemental sulfur. Research Triangle Institute also developed and tested a zinc titanate sorbent that showed sufficient potential for use in clean coal technology gasification combined-cycle projects.

In a separate project, the Calderon Energy Company (Bowling Green, Ohio) successfully operated its gasification-hot-gas cleanup process development plant for an initial 48-hour run in which the system's three major subsystems functioned together for the first time. The plant ran at a steady state, and initial measurements indicated sulfur removal efficiencies ranging from 86 to 99 percent. During 1993, tests focused on the limestone regeneration subsystem.

Low-Btu Combustion Tests

Even though combustion of low-Btu coal gas in a gas turbine results in lower levels of NO_x pollutants than direct coal combustion, improved gas combustion techniques offer opportunities for even lower NO_x emissions. In DOE's program to develop such technology, General Electric obtained impressively low NO_x emissions (less than 6 parts per million) and carbon monoxide emissions (less than 5 parts per million) at its Turbine Development Center in Schenectady, New York. In future tests, ammonia will be added to the simulated coal gas to further reduce NO_x emissions. The tests are a cooperative effort between DOE, General Electric, and the Electric Power Research Institute (Palo Alto, California).

Advanced Power Systems—Supporting Research and Development

DOE's Coal Preparation, Flue Gas Cleanup, and Waste Management programs support a number of advanced power systems applications. These programs are described in the following paragraphs.

Coal Preparation

In 1993, DOE neared completion of its 5-year Acid Rain Control Technology Program that assisted industry in developing advanced coal cleaning technologies. Three firms demonstrated coal-cleaning methods at the proof-of-concept scale, using physical means to separate impurities from coal. Southern Company Services completed operation of a selective agglomeration unit at Wilsonville, Alabama, that removed 67 to 83 percent of the pyritic sulfur from three high-sulfur bituminous coals. ICF Kaiser (Pittsburgh, Pennsylvania) tested an advanced-column flotation process at a State of Ohio research facility near McConnelsville, Ohio. Finally, Coal Technology Corporation (Bristol, Virginia) is completing detailed engineering design and will begin construction and testing of an advanced cycloning circuit. Coal Technology Corporation expects to complete the tests in early 1994.

In 1992, construction of a new Coal Preparation Process Research Facility (an interior view of which is shown in Figure 3-4) was completed at DOE's Pittsburgh Energy Technology Center. The coal preparation industry will use this facility to test a wide variety of advanced cleaning, processing, and handling equipment for fine coal. In 1993, DOE selected the first three developers to conduct tests of their processes at the facility. The three were Process Technology, Inc. (Houghton, Michigan), to test a new online slurry analyzer for ash and sulfur that can be used with froth flotation cleaning systems; AMAX Research and Development Center (Golden, Colorado), to test a micronized magnetite cycloning technology; and Virginia Polytechnic Institute (Blacksburg, Virginia), to test a combination of gravity and surface-effect cleaning methods.

In a separate effort, Coal Technology Corporation developed and tested a method for separating coal fines from water left over from water-based coal-cleaning processes, such as froth flotation. Researchers found that their high-gravity centrifuge, made up of a rotating bowl, an armlike filling and cutting system, and a computerized drive assembly, can effectively dewater coal fines while avoiding problems associated with thermal drying techniques.

In addition to preventing acid rain emissions, DOE's coal preparation program is developing premium ultraclean fuels for power generation. In September 1992, DOE awarded a 4-year contract to AMAX Research and Development Center to provide the engineering design base for advanced-column flotation and selective agglomeration techniques capable of producing clean coal with sulfur at 0.6 pound or less per million Btu (260 grams or less

3-4. An interior view of the newly built Coal Preparation Process Research Facility at the Pittsburgh Energy Technology Center, where a wide variety of advanced fine-coal cleaning, processing, and handling processes can be evaluated.

per gigajoule) and ash at 2.0 pounds or less per million Btu (860 grams or less per gigajoule). The processing cost to produce the ultraclean coal is not to exceed \$2.50 per million Btu (\$2.65 per gigajoule). Such deep cleaning should significantly reduce the trace element content of the coal, thereby reducing the subsequent emission of hazardous air pollutants. A secondary goal is to apply the advanced processes to the processing of clean coal fines (the smallest size fraction left from conventional coal-cleaning processes) that otherwise would be discarded.

In 1992-1993, DOE completed its project with TRW to develop the firm's molten caustic leaching technology, a chemical coal-cleaning method. In the final stages of the project, TRW produced coals with sulfur contents as low as 0.1 percent. The projected cost of converting raw coal into this superclean fuel, once as high as \$88 per ton (\$64 per metric ton), has fallen by about 35 percent because of process improvements demonstrated by TRW.

Flue Gas Cleanup

In 1992–1993, DOE also completed another element of its near-term program to reduce acid-rain-causing emissions by meeting the major objectives in its duct injection Acid Rain Control Initiative. Tests at a powerplant in Beverly, Ohio, by Gilbert Commonwealth (Reading, Pennsylvania) and Southern Research Institute (Birmingham, Alabama) showed that 70 percent of the SO_2 in flue gases could be captured. Sorbent use was cut in half by recycling a portion of the unreacted lime that is filtered out with the fly ash. The test data were used to produce a duct injection technology design handbook that provides process, equipment, and economic information needed to design and retrofit a commercial duct injection system.

In a cost-shared effort between DOE, the Electric Power Research Institute, and six host utilities, five full-scale tests of additives to enhance the performance of wet scrubbers were conducted in 1992, with a sixth test planned for late 1993. Early tests showed some of the additives capable of increasing the effectiveness of sulfur capture from 90 percent to nearly 99 percent. Radian Corporation (Austin, Texas) oversaw the tests, which will show utilities relatively inexpensive ways to comply with the Clean Air Act Amendments of 1990 during this decade.

Another type of scrubber additive—a metal chelate—was shown in 1.5-megawatt (equivalent) slipstream tests to be a low-cost way of capturing NO_x emissions from coal-fired powerplants. Dravo Lime Company (Pittsburgh, Pennsylvania) conducted the tests.

In 1992–1993, Energy and Environmental Research Center and Owens-Corning Fiberglass, Inc. (Corning, New York), tested another NO_x -flue-gas-cleaning process. These tests showed that a catalytic fabric filter can remove more than 80 percent of NO_x and 99.9 percent of fine particulates from coal combustion gases. The technique also is likely to be effective in capturing air toxic emissions.

Environmental Research Corporation (Irvine, California) developed another promising NO_x control technique, called the CombiNOx process, that can capture 85 percent of NO_x emissions by combining advanced coal reburning and selective noncatalytic reduction with urea and methanol injection.

In late 1992, in the area of combined sulfur and nitrogen flue gas controls, NOXSO Corporation (Pittsburgh, Pennsylvania) completed proof-of-concept tests of the NOXSO technology at Ohio Edison's Toronto station. The tests verified the technique's potential for removing more than 90 percent of sulfur and nitrogen pollutants, while creating no waste products. NOXSO Corporation logged more than 3,000 hours of operation at the facility. The

corporation used the test data in the design of a full-scale NOXSO system to be demonstrated in a third-round clean coal technology project sponsored by M.K. Ferguson Company (Cleveland, Ohio).

In 1992, tests of another promising combined NO_x - SO_2 control process, called the SOXAL process, were also under way. In this regenerative sodium-based flue gas treating system, more than 99 percent of the SO_2 in flue gas can be recovered in a form that can be converted to sulfuric acid, liquid SO_2 , or elemental sulfur, while urea or methanol injection is used to reduce NO_x . The tests took place with a 3-megawatt slipstream of combustion gases at Niagara Mohawk's Dunkirk station in Dunkirk, New York.

Two researchers from the Pittsburgh Energy Technology Center received the Federal Laboratory Consortium's Award for Excellence in Technology Transfer for 1993. The researchers developed a patented NO_x control method that was subsequently licensed to the NOXSO Corporation for use in the company's flue gas cleanup process.

Waste Management

Solid wastes from coal combustion (fly ash, bottom ash, and flue gas desulfurization wastes) are the second largest type of waste material produced in the United States. Landfill disposal costs are rapidly rising as land becomes less available and as disposal regulations tighten. For these reasons, DOE continued to examine ways to minimize or recycle coal combustion wastes into marketable products.

In a multiyear project led by Dravo Lime Company, a team of utilities is working with the Ohio State University and the Ohio Coal Development Office to develop uses for wastes from two clean coal technologies: pressurized fluidized-bed combustion and limestone injection multistage burners. Because of the addition of limestone sorbents in these processes, the wastes can be beneficial in other applications. For example, Ohio State University completed greenhouse plant growth studies that showed that the alkaline wastes from the two advanced clean coal technologies can remediate the acid soil created by coal mining. Both materials proved to be effective in neutralizing the soil's acids and promoting plant growth, and researchers noted no significant uptake of heavy metals. Dravo also used spray dryer residues to build a truck ramp on the campus of Ohio State University to demonstrate the use of waste as a structural fill material.

To assess the impact of landfills to dispose of solid wastes from advanced coal technologies, Radian Corporation built large-scale test units using wastes from two clean coal technology projects. In Nucla, Colorado, the corporation built a test cell of 700 tons (635 metric tons) of wastes

from a circulating fluidized-bed combustion plant, and in Lorain, Ohio, it built two similar-size test cells with waste from the limestone injection multistage burners project. After 3 years of comprehensive environmental monitoring, no significant effect on the environment was evident, providing assurance that wastes from these advanced technologies could be treated in the same manner as ordinary coal combustion wastes.

TRANSPORTATION FUELS FROM COAL

As the Nation's largest user of petroleum, the transportation sector is the primary reason for the increasing U.S. dependence on imported oil. Research sponsored by DOE and others has reduced costs (after full-scale development) for coal-derived transportation fuels in recent years—they are now in the range of \$30 to \$35 per barrel—and there may be opportunities for further cost reductions and for nearer term introduction of coal-based fuels, or more likely, of fuel additives.

In 1992, DOE adopted a strategic goal for its coal-to-liquids program: by 2010, to demonstrate advanced concepts for producing environmentally clean liquids that can compete with natural products at a cost of no more than \$30 per barrel (\$220 per metric ton) of oil equivalent (in 1991 dollars after full-scale development).

Indirect liquefaction technologies, such as the Fischer-Tropsch process, produce a wide range of liquid fuels from coal via an intermediate gasification step. In August 1992, DOE successfully completed the first proof-of-concept demonstration of the slurry-phase Fischer-Tropsch process. Although Fischer-Tropsch is a proven technology, researchers believe that passing the reactant gas through a slurry containing suspended catalyst particles, rather than through a fixed bed of catalyst as is done commercially, can greatly improve efficiency and reduce costs. The test run, which took place at DOE's Alternative Fuels Development Unit in LaPorte, Texas, indicated that the reactor performed well in converting the gases to liquid products and that the catalyst remained stable throughout the run. The test produced high-quality fuels that exceeded the future specifications mandated by the Clean Air Act Amendments of 1990. Air Products and Chemicals, Inc., performed the test, with cost sharing from Exxon (Florham Park, New Jersey), UOP, Inc. (Des Plaines, Illinois), Statoil (Norway), and Shell Oil Corporation (Houston, Texas).

Also in 1992–1993, scientists at Texas A&M University (College Station, Texas) synthesized a new catalyst

for use in the Fischer-Tropsch process. They found the catalyst to be 25 percent more active than iron-based catalysts, which could lead to reduced overall production costs and improved product quality.

The earliest market entry for coal in the area of transportation fuels may be for fuel additives and octane enhancers made from coal-derived synthesis gas. With DOE support, Air Products and Chemicals, Inc., has developed technology for converting synthesis gas to methyl tertiary butyl ether. Economic analyses showed that with only a modest improvement in catalyst performance, the proposed route to methyl tertiary butyl ether from coal (or natural gas) could be cost-competitive with conventional sources by the mid- to late 1990s.

In a separate project, Amoco Oil Company (Naperville, Illinois) found that iso-olefins, key components used to produce reformulated gasolines required by the Clean Air Act Amendments of 1990, can be produced by catalytically cracking the wax byproduct from the Fischer-Tropsch process. Yields of isobutylene were up to six times higher than those from petroleum-based processes, while the yield of isoamylene was more than twice as high.

In the area of biological conversion, researchers at Engineering Resources, Inc. (Fayetteville, Arkansas), identified a bacterial strain that is highly effective in converting synthesis gas to ethanol, a component of reformulated gasoline. The organism tolerates sulfur and could offer considerable cost savings for alcohol production by not requiring a sulfur removal stage. Current research is focused on increasing the conversion rate by operating the process at higher pressures.

Direct liquefaction involves the direct hydrogenation of coal to produce premium transportation fuels from coal. In 1992, DOE continued its direct liquefaction research with two awards to HRI, Inc. (Princeton, New Jersey), for bench-scale and proof-of-concept testing. The smaller, bench-scale unit is capable of processing 25 pounds (11 kilograms) of coal per day and will be used to pioneer new research concepts that will then be scaled up to the 3-ton-per-day (2.7-metric-ton-per-day) proof-of-concept plant.

Improved catalysts have the potential to reduce the cost of direct liquefaction by enabling the use of a slurry reactor that is less expensive to build and that allows for a higher throughput than the current ebullated-bed-type reactor. Researchers at the University of Pittsburgh developed a new family of fine-particle catalysts based on sulfated oxides of iron. Initial testing by Amoco Oil Company showed that these disposable catalysts result in high coal conversions and high yields of oil at relatively mild conditions.

Also in 1992, Amoco Oil Company and Bechtel Corporation completed a cost estimate for the design, construction, and operation of a commercial direct liquefaction plant in southern Illinois using data generated from DOE-sponsored tests. The study showed that, at 1992 coal prices, coal liquids could be competitive at an equivalent selling price of \$33.45 per barrel (\$244 per metric ton) after full-scale development. The study found that use of natural gas to produce hydrogen (instead of the more costly coal gasification route) might further reduce the price to \$31 per barrel (\$226 per metric ton). These price projections are significant improvements over the \$65 to \$90 prices typical of processes studied in the 1970s. Bechtel Corporation expects to complete a study based on lower rank coals in 1993.

COAL FOR NONUTILITY MARKETS

DOE completed several projects in 1992–1993 to develop technologies that would enable coal to compete in nonutility markets. These projects are described in the following paragraphs.

Pennsylvania State University (University Park, Pennsylvania) completed baseline tests for a planned demonstration of the use of superclean coal-water fuels in industrial-sized boilers that were designed to burn oil. The university installed a commercial, 20-million-Btu-per-hour (21-gigajoule-per-hour) oil-designed watertube boiler, along with a baghouse for particulate collection, at the east campus steam plant.

In a similar project completed in April 1993, Energy and Environmental Research Corporation (Orville, Ohio) converted a small, commercial-scale oil-designed boiler at the University of Alabama to burn coal-water fuel. The boiler completed several hundred hours of operation.

Vortec Corporation (Collegeville, Pennsylvania) showed that glass-and mineral fiber products can be produced in a specially designed coal combustor from a variety of feedstocks, including coal ash, sewage sludge, waste container glass, and glass and fiber process waste. Economic studies showed that, compared to a more traditional gas-fired technology, the Vortec system can increase the efficiency of the glass-melting process and decrease capital costs by about 25 percent. The technology also has the potential to recycle waste fiberglass, which must now be landfilled, and to vitrify hazardous wastes into a nonleachable product. Vortec's multifuel, glass-melting furnace appears in Figure 3–5.

3–5. Vortec Corporation's multifuel glass-melting furnace that made glass and mineral fiber products from a variety of feedstocks, including coal ash, sewage sludge, waste glass, and fiber process waste.

In 1992–1993, engineering tests were completed on three other combustion systems being developed for industrial and commercial application. ABB Combustion Engineering completed development of a micronized coal-fired burner for industrial markets with tests at a 20-million-Btu-per-hour (21-gigajoule-per-hour) watertube boiler at Pennsylvania State University. Manufacturing and Technology Conversion International (Columbia, Maryland) outfitted a 5-million-Btu-per-hour (5-gigajoule-per-hour) firetube boiler at a warehouse in Baltimore with a pulverized coal-fired, pulsed combustor. Tecogen, Inc. (Waltham, Massachusetts), developed a coal-water-slurry-fired cyclone combustor (which includes a fuel preparation subsystem, a combustor, a 4-million-Btu-per-hour (4-gigajoule-per-hour) firetube boiler, and an emissions control system) to heat a research laboratory at Southern Illinois University (Carterville, Illinois).

In May 1993, Energy International Corporation (Pittsburgh, Pennsylvania) completed work on a novel technology to convert wet filtercake, a mudlike form of finely ground clean coal that is difficult to handle, into a granular form that can be readily stored and transported. Called mulled coal, this superficially dry, sandlike material can be handled in conventional equipment and resists the effects of rain and other weather conditions.

In 1993, DOE began wrapping up its programs to develop coal-fueled turbine and diesel engines. Cooper-Bessemer and Arthur D. Little successfully demonstrated a 2-megawatt, six-cylinder diesel engine system that ran on coal-water slurry fuel, along with a companion emission control system designed to meet New Source Perfor-

mance Standards. The diesel achieved up to a 42-percent thermal efficiency in simple cycle operation—the same level that could be achieved using natural gas. A 14-megawatt version of the technology was selected in the fifth round of the Clean Coal Technology Program. The Allison Gas Turbine Division of the General Motors Corporation (Indianapolis, Indiana) successfully operated a gas turbine combustion system that was directly fired with coal-water slurries. In 1993, Allison Gas Turbine conducted tests with a more economical dry-feed system.

In a spinoff application for fluidized-bed coal combustion, DOE and Donlee Technologies (York, Pennsylvania) continued work in Lebanon, Pennsylvania, to build an advanced boiler that would burn coal with hospital waste to provide steam for the hospital while solving a growing disposal problem. Donlee will build a 10-ton-per-hour (9-metric-ton-per-hour) steam circulating fluidized-bed combustion boiler at the Lebanon Veterans Medical Center. In 1993, DOE completed the preconstruction environmental review process with the publication of a finding of no significant impact, as required by the National Environmental Policy Act.

ADVANCED CROSSCUTTING RESEARCH

DOE's Office of Fossil Energy also conducts a broad-based program of crosscutting research that can benefit a wide range of coal technologies. Much of this work involves the development of new materials for advanced coal processes, such as structural and functional ceramics and new alloys.

Ceramic composites research has focused on silicon carbide composites for use in high-temperature heat exchangers, particulate filters for hot-gas cleaning, and other components in coal combustion and gasification applications.

During 1992, work was completed on a cooperative research and development agreement that led to the transfer of a forced chemical vapor infiltration process, developed by Oak Ridge National Laboratory, to the Minnesota Mining and Manufacturing (3M) Company (St. Paul, Minnesota). 3M has produced full-size ceramic composite candle filters using the national laboratory-developed technology. These high-purity silicon carbide matrix filters are lighter and more resistant to thermal and mechanical shock and chemical degradation than the monolithic ceramic candle filters now being tested in coal combustion and gasification applications. Ceramic composite filters are likely to be the first commercial use of the ceramic composites technology developed at Oak Ridge.

Also in 1992–1993, inorganic membranes for high-temperature hydrogen and other gas separations continued to be improved through DOE-sponsored research. Alumina membranes with pore diameters less than 10 angstroms (1 nanometer) (close to the size needed to separate hydrogen) were produced at the Oak Ridge K-25 site and tested at temperatures up to 600 degrees Celsius and at pressures of up to 600 pounds per square inch (4.1 megapascals).

Iron aluminide intermetallic alloys are being developed for applications that require superior oxidation and sulfidation resistance in high-temperature environments. More than 30 companies are working with Oak Ridge National Laboratory to move this promising intermetallic alloy into the marketplace in such applications as pipes and valves, filters, steam turbine components, pumps, boiler tubes and hardware used in fossil energy boiler systems, and spinoffs such as automotive exhaust systems and regenerators in gas turbine engines.

PETROLEUM TECHNOLOGY

In October 1992, a panel of 17 oil experts assembled by DOE concluded that the United States may have far more producible crude oil in existing fields and undiscovered formations than is commonly believed. According to the panel, reasonable estimates of the Nation's recoverable crude oil could be from two to four times the 26 billion barrels (3.6 billion metric tons) currently accepted as the Nation's remaining producible oil at current prices and using today's technology. Much of the additional oil could come from yet-to-be-discovered formations in the lower 48 states and in Alaska. Far from the perception that all the Nation's petroleum has been found, the panelists concluded that from 25 to 60 billion barrels (3.4 billion to 8.2 billion metric tons) could come from so-called undiscovered resources. Another 26 to 78 billion barrels (3.6 billion to 10.7 billion metric tons) could come from expanding existing fields or by locating bypassed pockets of oil between existing wells or by producing oil from deeper formations.

The panel's findings gave added impetus to DOE's program to develop improved exploration and production technologies. Panel members wrote in their final report that "the exploration for and the development and production of oil have long had strong technological components, but today and in the future, technological dependence will be foremost."

In 1992, to assist the oil industry, particularly independent producers, in developing and deploying more effective technology, DOE announced specific strategic objectives for its Oil Recovery Program:

1. By 1995, complete initiation of major technology transfer activities, including demonstrations of existing improved oil recovery technology that can forestall abandonments and extend the economic life of high-priority, light oil reservoirs
2. By the year 2000, complete demonstrations and other technology transfer activities for operators of high-priority reservoirs, including demonstrations of the best, currently defined advanced technologies to maximize incremental recovery

Reservoir Class Field Program

In 1992–1993, DOE's joint effort with industry moved from the planning stages to the selection of field projects targeted for Federal funding. The Reservoir Class Field Program's purpose is to assist operators demonstrate technologies that can prolong the economic life of many of the Nation's aging oil fields and, in turn, to slow the decline of domestic oil production.

For each round in the program, DOE is identifying a specific geologic class of oil-bearing reservoirs that has large volumes of oil remaining, yet faces near-term abandonment.

Class 1

On April 22, 1992, DOE announced its selection of 14 projects in the first reservoir class, the fluvial-dominated deltaic sandstone reservoirs. (The name comes from the fact that sediments of deltas from ancient rivers formed the reservoirs.) DOE is providing more than \$48 million in Federal cost sharing to the winning projects, which have a total value in excess of \$110 million. If the technologies prove successful, and if the companies replicate them throughout areas where fluvial-dominated deltaic reservoirs exist, as much as 6.3 billion barrels (860 million metric tons) of crude oil could be added to the Nation's recoverable reserves, according to the companies' estimates.

The Department selected the projects in two groups. Ten projects will concentrate on near-term, commercially available approaches. The objective is to increase confidence that declining oil fields can be kept in production

long enough for better technologies to be developed. These projects were proposed by American Oil Recovery, Inc. (Decatur, Illinois) (project site: Mattoon Oil Field, Illinois), Anderman-Smith Operating Company (Denver, Colorado) (project site: Black Warrior Basin, Alabama), Lomax Exploration Company (Salt Lake City, Utah) (project site: Monument Butte Field, Utah), Research and Engineering Consultants, Inc. (Englewood, Colorado) (project site: Sooner Field, Colorado), Sierra Energy Company (Reno, Nevada) (project site: Badger Basin, Wyoming), University of Kansas Center for Research, Inc. (Lawrence, Kansas) (project sites: the Savonburg and Stewart fields in Kansas), the University of Oklahoma (Norman, Oklahoma) (project sites: statewide survey), the Bureau of Economic Geology at the University of Texas (Austin, Texas) (project site: Vicksburg Fault Zone in south Texas), the University of Tulsa (Tulsa, Oklahoma) (project site: Glenn Pool Field, Oklahoma), and the Utah Geological Survey (Salt Lake City, Utah) (project site: Bluebell Field, Utah).

Four projects will demonstrate more advanced technologies that could help boost oil production within the next 10 years. These were proposed by the Amoco Production Company (Houston, Texas) (project site: West Hackberry Field, Louisiana), Columbia University (Palisades, New York) (project site: Eugene Island Block 330, offshore Louisiana), Hughes Eastern Corporation (Jackson, Mississippi) (project site: North Blowhorn Creek Field, Alabama), and Texaco Exploration and Production Company, Inc. (New Orleans, Louisiana) (project site: Port Neches Field, Texas).

Class 2

On April 20, 1993, DOE added a second set of oil recovery projects, this time focusing on shallow-shelf carbonate reservoirs (oil-bearing reservoirs formed millions of years ago in near-shore ocean coastal regions). Domestic shallow-shelf carbonate reservoirs once contained more than 68 billion barrels (9.3 billion metric tons) of crude oil, about one-seventh of the total crude oil discovered in the lower 48 states. Although nearly 20 billion barrels (2.7 billion metric tons) have been produced to date, less than 4 billion barrels (550 million metric tons) remaining can be economically produced with current practices. Greater use of improved secondary and tertiary oil recovery methods could nearly triple the amount of oil that could be produced from these reservoirs, perhaps adding another 7.5 billion barrels (1.0 billion metric tons) of reserves.

As in the first competition, DOE selected the class 2 proposals in two groups: those that employ near-term tech-

nologies and those that will demonstrate more advanced, midterm technologies.

The near-term winning proposals were submitted by Beard Oil Company (McCook, Nebraska) (project site: Palisades Producing Complex, Nebraska), Laguna Petroleum Corporation (Midland, Texas) (project sites: Grayburg and San Andres Formations of west Texas), Michigan Technological University (Houghton, Michigan) (project site: Dundee Formation, Michigan), Research and Engineering Consultants, Inc. (Englewood, Colorado) (project site: southern Williston Basin of Montana and North Dakota), Seagull Mid-South (Shreveport, Louisiana) (project site: North Eastman Field, Oklahoma), Texaco Exploration and Production, Inc. (Midland, Texas) (project sites: Grayburg and San Andres Formations in eastern New Mexico), University of Kansas Center for Research, Inc. (Lawrence, Kansas) (project sites: Petersilie Field and Bindley Field, Kansas), and the Utah Geological Survey (project sites: Paradox Basin of Utah, Colorado, and Arizona).

The midterm projects selected were submitted by Fina Oil and Chemical Company (Midland, Texas) (project site: Robertson Clearfork Unit of the Permian Basin in west Texas), Oxy USA, Inc. (Midland, Texas) (project site: West Welch Unit of the Permian Basin in west Texas), and Phillips Petroleum Company (Odessa, Texas) (project site: South Cowden Unit of the Permian Basin in west Texas).

Oil Recovery—Supporting Research and Development

Complementing the Reservoir Class Field Program are ongoing analyses, planning, and research to improve reservoir modeling, geophysical characterization technology, environmental analysis, fracture detection, and advanced recovery technologies.

In April 1992, DOE selected Continental Shelf Associates, Inc. (Jupiter, Florida), to conduct a 3-year study of the environmental and health impacts of wastewater and sand discharged from oil and gas production in and around the Gulf of Mexico. The firm would head a seven-company team of scientific experts that will examine the impact of produced water and sand discharges on the coastal ecosystem. The team would also evaluate the economic effects of effluent guidelines recently proposed by the Environmental Protection Agency, as well as the impact of similar regulations proposed at the state level.

Also in April 1992, DOE selected six universities and one small business to conduct enhanced oil recovery re-

search using chemical flooding advanced recovery techniques that are expected to increase predictability and improve performance of oil recovery processes. DOE will fund a total of approximately \$4.5 million; proposed private-sector cost sharing totaled slightly more than \$1.5 million.

In June 1993, DOE chose seven research teams, headed by universities and a state geological survey, to conduct projects that would develop better geoscience and reservoir engineering tools. The 3-year projects will focus on applying advanced geoscience and reservoir engineering concepts to give oil operators a better picture of a reservoir's characteristics, which could lead to more effective production methods.

In December 1992, in the area of microbial oil recovery, DOE's National Institute for Petroleum and Energy Research at Bartlesville, Oklahoma, reported a 17-percent incremental oil recovery using their microbial enhanced recovery process at a 520-acre (210-hectare), 66-well stripper field in Oklahoma. The institute also completed a comprehensive microbial recovery project data base in 1993.

ParaMagnetic Logging, Inc. (Woodinville, Washington), completed a nonexclusive patent and license agreement to commercialize its technology to survey for oil and gas in metal-cased holes. Major and independent oil companies have expressed an interest in using the technology in the Permian Basin and on the Alaskan North Slope.

Oil Technology Transfer

The true measure of success of DOE's petroleum program will be the increase in industry adoption of oil field innovations. Technology transfer, therefore, is one of the key elements of the program and perhaps the most important.

Each organization receiving Federal cost sharing in the Reservoir Class Field Program is required to undertake an aggressive technology transfer effort. DOE also maintains separate efforts intended to transfer more effective technology to the oil industry, particularly the independent producer.

In 1992–1993, DOE assisted the oil and gas industry in its creation of the Petroleum Technology Transfer Council, an ad hoc industry-led council that will address the technology needs of the U.S. oil- and gas-producing community and identify the best means for improving technology transfer to domestic producers. The council will oversee a series of workshops throughout oil- and gas-producing regions of the country, first to identify technical obstacles confronting operators and then to convey

specific technical solutions to the highest priority problems. The council would also help to establish information resource contacts in or near producing regions to give operators access to the latest technical information. In May 1993, the council submitted a plan to DOE that is expected to serve as a key element in the Department's 5-year oil and gas technology transfer plan to be submitted to Congress in late 1993.

Also in 1992–1993, DOE, through its Bartlesville Project Office, supported a series of workshops sponsored by the Texas Independent Operators and Royalty Owners Association that provided nearly 500 independent operators in Texas with technology to help increase oil and gas production. DOE also funded a 1-year project by the University of Kansas Energy Center to expand and adapt its highly successful oil field assistance program, the Tertiary Oil Recovery Program, as a problem-solving tool in other oil-producing states.

DOE also supported several national and international meetings that offer an opportunity to exchange information and data on oil research, including the Enhanced Oil Recovery Symposium jointly sponsored by DOE and the Society for Petroleum Engineers (April 1992); the Midcontinent Geological Workshops cosponsored with the Oklahoma Geological Survey (March 1993), which included a workshop on class 1 fluvial-dominated deltaic reservoirs; and the Microbial Enhanced Oil Recovery Conference (September 1992).

In March 1993, the Bartlesville Project Office awarded a grant to the American Geologic Institute for a study to establish a National Geoscience Data Repository. The goal of the repository would be to save billions of dollars worth of oil industry geologic and geophysical data in danger of being lost because of the decline in domestic exploration and production, especially by major oil companies.

As part of the Oil Recovery Technology Partnership, a program that applies technology developed at DOE's national laboratories to solve specific oil and gas production problems, work continued that will help industry increase efficiency of oil recovery processes. The partnership has led to the development of commercial seismic devices, successfully tested in 1992 and made available to industry in 1993, that offer an order of magnitude higher resolution in detecting oil-bearing deposits.

Bartlesville Research Facility

In May 1992, DOE opened a competition for a new operator for its principal petroleum research facility (once

a federally run energy technology center) in Bartlesville, Oklahoma, formerly known as the National Institute for Petroleum and Energy Research. In conducting the competition, DOE indicated that, in addition to onsite research, facility staff would play an expanded role in implementing the national oil recovery program, including monitoring projects selected in the Reservoir Class Field Program.

On March 26, 1993, the Department selected BDM-Oklahoma, Inc. (Tulsa, Oklahoma), which had teamed with the University of Tulsa, to negotiate a new management and operating contract for the facility. The 5-year contract could be worth more than \$200 million in Federal funding for petroleum-related research and field testing; data processing; and facilities operation, maintenance, and construction.

Oil Shale Research and Development

Lawrence Livermore National Laboratory successfully operated its hot-recycled-solid retort, a 4-ton-per-day pilot plant, for a total of 104 hours. Trial runs have shown that hot ceramic filters are superior, dust-free oil recovery systems. Spent shale from several tests using various operating conditions have met, by factors of 10 to 100, Federal and state regulatory limits. In a separate effort, the University of Kentucky's KENTORT system for eastern shale, designed to produce oil with brick and cement products, was hot-tested at a scale of 50 pounds per hour.

J.W. Bunker and Associates (Salt Lake City, Utah) received a contract to determine the technical and economic feasibility of producing high-value products (such as resins, paints, waxes, pharmaceutical, asphalt additives) from shale oil. This research may increase the market value of shale oil to as much as \$90 per barrel.

NATURAL GAS RESEARCH AND DEVELOPMENT

In December 1992, the National Petroleum Council added further justification to the view that the United States is a natural-gas-rich country. The council completed an extensive, 2-year analysis with the issuance of a comprehensive study titled "The Potential for Natural Gas in the United States."

In the study, the council estimated that as much as 1,295 trillion cubic feet (37.7 trillion cubic meters) of natural

gas is technically recoverable in the lower 48 states. In addition to the current proved reserves of 160 trillion cubic feet (5 trillion cubic meters) (as of January 1, 1992), the United States has an estimated 616 trillion cubic feet (17.4 trillion cubic meters) of recoverable gas resources in conventional formations and perhaps another 519 trillion cubic feet (14.7 trillion cubic meters) in nonconventional resources such as coal seams, shales, and tight sandstone formations.

The council stressed, however, that these estimates depend on the continued development of improved extraction technologies. "As reflected in the 1,295 TCF [37.7-trillion-cubic-meter] recoverable resource estimate," according to the council's report, "the contribution of technology is expected to increase the lower-48 recoverable natural gas resource base by more than 200 TCF [5.7 trillion cubic meters] between 1990 and 2010."

Resource and Extraction

DOE's Natural Gas Resource and Extraction Program focuses on developing many of the improved extraction technologies identified in the National Petroleum Council study. DOE has placed considerable emphasis on developing better drilling techniques, increasing the accuracy of diagnostics, and improving technologies for reservoir characterization for all gas-bearing formations. DOE and its contractors are studying both conventional and nonconventional resources.

Directional drilling offers a low-cost and effective alternative to conventional vertical wells that require hydraulic fracturing, especially in areas with tight formations that are difficult and costly to produce. In 1993, the Department's Morgantown Energy Technology Center completed the Slant Hole Drilling Test in western Colorado. The test-well produced gas at rates 5 to 10 times those of surrounding conventional wells. As a result of the field demonstration, several companies drilled horizontal wells, including a project announced by Barrett Resources (Denver, Colorado) for an eight-well directional drilling program that will expand this new tight gas development technology to other leases throughout Colorado and Wyoming. For its performance, the horizontal well was named "Best Well of 1992" by *Western Oil World* magazine. Figure 3-6 is a photograph of the rig that undertook the directional drilling test in western Colorado.

Working with funding from DOE and the Gas Research Institute, the Bureau of Economic Geology of the University of Texas completed an initial 4-year effort to study

3-6. A view of the Slant Hole Drilling Test in western Colorado that used the directional drilling technique. The test-well produced gas rates 5 to 10 times those of wells in surrounding western Colorado.

gas bypassed by normal production in the Texas Gulf Coast Basin. The study confirmed that conventional drilling and production technologies may have missed substantial quantities of natural gas. Researchers found significant quantities of natural gas in untapped compartments of reservoirs and in sections of mature fields that were not fully drained. To determine whether similar quantities of bypassed gas exist elsewhere, DOE and the Gas Research Institute extended the project to study deltaic sandstone and carbonate reservoirs in the midcontinent region of the United States.

Progress also continued on a project by West Virginia University to develop an atlas of major gas plays in the Appalachian region. The university has teamed with state geologic surveys in Kentucky, Ohio, Pennsylvania, and West Virginia to classify gas reservoirs by geologic plays. The goal is to enable gas producers to devise more effective

tive exploration strategies. Under the project, all gas reservoirs in the Appalachian region have been assigned to one of 34 gas plays, and data acquisition and compilation are in progress. DOE, along with the Gas Research Institute, is planning development of several other atlases for Texas, the Rocky Mountains, Illinois-Michigan, the West Coast, and offshore areas.

Deliverability

In September 1992, in a major study issued jointly by DOE and the Federal Energy Regulatory Commission (*Natural Gas Deliverability Task Force Report*, DOE FE-0258P), the two agencies concluded that establishing an information system that can reliably and accurately report the deliverability of natural gas supplies will be critical to building a more efficient, cost-effective, and competitive natural gas market that will benefit producers, transporters, and consumers. The study further concluded that Federal and state agencies need to work with the private sector to overhaul the current outmoded deliverability reporting system.

According to the study, price decontrol and interstate open-access policies are creating an entirely new industry structure that needs a new information base to support it. The report's recommendations centered on three themes:

1. Information needs to be refocused to serve those who buy and sell both natural gas and pipeline capacity, instead of the current emphasis on serving the needs of traditional regulators
2. Buyers and sellers need easy and timely access to information, so electronic bulletin boards should be incorporated at major market centers
3. The information system should be retooled to encourage private-sector flexibility and innovation

To upgrade state data collection, DOE entered into a cofunded research program with the Interstate Oil and Gas Compact Commission and the University of Oklahoma to determine what hardware and software will be necessary for a national data collection program. When complete, the product will be a prototype data model for use by gas-producing states.

As another response to recommendations in the DOE-Federal Energy Regulatory Commission study, DOE's Office of Fossil Energy expanded its electronic information services to include a publicly accessible computer

bulletin board with information on natural gas import and export authorizations and permits for transboundary electric transmission lines.

Natural Gas Utilization

The largest percentage of DOE funding for natural gas research and development is for new technologies that can increase the use of natural gas in existing and new markets. Within the Fossil Energy Program, activities are under way in natural-gas-powered fuel cells, advanced gas turbines, and conversion of natural gas to liquids.

Fuel Cells

In 1992, DOE concluded its program to develop phosphoric acid fuel cells, and the technology began to attract its first commercial customers. ONSI Corporation (South Windsor, Connecticut), a subsidiary of International Fuel Cells, began manufacturing a line of 200-kilowatt phosphoric acid fuel cell powerplants based on technology cosponsored by DOE. These units are designed for distributed electric power production and cogeneration. During 1992 and 1993, more than 55 units will be delivered to electric and gas utilities in Europe, Japan, and the United States. Also in 1992, International Fuel Cells manufactured the power section for an 11-megawatt utility powerplant made up of eighteen 700-kilowatt stacks and successfully operated the plant in utility service.

With its efforts completed in first-generation phosphoric acid fuel cells, DOE concentrated its 1992-1993 Fuel Cell Program on the more advanced, higher efficiency molten carbonate and solid-oxide fuel cell technologies.

In November 1992, the Department announced that it had signed two new agreements to supply full-size, molten carbonate fuel cell power-generating stacks for field tests at a municipal utility powerplant and a hospital in California.

One agreement calls for the Fuel Cell Engineering Corporation, a subsidiary of Energy Research Corporation (Danbury, Connecticut), to supply stacks for a 2-megawatt powerplant at Santa Clara, California. DOE will fund two eight-stack modules and related hardware for the Santa Clara powerplant. The balance of the plant will be financed by a consortium of five California utilities, the National Rural Electric Cooperative Association, the Electric Power Research Institute, and Energy Research Corporation.

The second agreement will supply stacks fabricated by M-C Power Corporation (Burr Ridge, Illinois) for a 250-kilowatt test facility at the Kaiser Permanente Medical

Center in San Diego, California. Cosponsors of the project, scheduled to be in operation in 1994, include the Gas Research Institute, the Electric Power Research Institute, Kaiser Permanente Medical Center, San Diego Gas and Electric (the project host), and M-C Power.

In January 1993, in preparing for the field-test program, Energy Research Corporation completed assembly of the world's largest molten carbonate fuel cell stack at its Danbury facility. The 6-square-foot (0.6-square-meter) fuel cell, nominally rated at 100 kilowatts, began performance testing later in the spring. In 1992, Energy Research Corporation also successfully tested a 70-kilowatt molten carbonate fuel cell test stack at the Pacific Gas and Electric test facility in San Ramon, California. The fuel cell operated for 1,500 continuous hours before its planned shutdown, with a total operating time of more than 2,000 hours.

In 1992, in the more advanced solid-oxide fuel cell technology, Westinghouse Electric developed a 25-kilowatt tubular solid-oxide fuel cell customer test unit for demonstration at Kansai Electric (Osaka, Japan). During initial acceptance testing, the unit ran for 709 hours, with maximum power of 34 kilowatts and fuel utilization of 83 percent. DOE expects the unit—the first customer test unit with alternating-current power output and cogenerated heat—to reach 40 kilowatts once steady-state voltage levels are attained. The test is likely to last 8,000 hours.

While these tests were under way, smaller Westinghouse Electric solid-oxide test cells passed the 35,000-hour-runtime milestone in February 1992. Each test unit consists of two cells that are 36 centimeters long with porous support tubes. Westinghouse Electric will continue to operate these cells to further extend life cycle data of solid-oxide fuel cells. About 50,000 hours will be required to support commercial operation.

High-Efficiency Gas Turbines

In 1992, DOE instituted a new, wide-ranging program to develop advanced natural-gas-fired turbine systems for the 21st century. DOE's goal, developed jointly with the Nation's turbine manufacturers, is to develop innovative turbine concepts that will offer much higher efficiencies and cleaner performance than today's state-of-the-art systems. Figure 3-7 depicts an artist's concept of an air-derivative gas turbine. Eventually, efficiencies exceeding 60 percent may be reached using such advanced technology.

The overall program is jointly administered by DOE's Office of Fossil Energy and the Office of Energy Effi-

3-7. An artist's concept of an air-derivative gas turbine, the type of advanced, highly efficient technology being developed by DOE in its natural gas utilization programs. The goal is to reach efficiencies that exceed 60 percent.

ciency and Renewable Energy. The fossil energy portion focuses on advanced utility-scale gas turbine systems with target efficiencies in excess of 60 percent. These advanced systems initially will burn natural gas but will later be adaptable to coal gasification combined-cycle, pressurized fluidized-bed combustion, indirect-fired cycle, and direct coal-fired gas turbine systems.

DOE's Office of Energy Efficiency and Renewable Energy will concentrate on developing advanced turbine systems for industrial power generation, cogeneration, and mechanical drive applications with a goal of improving system efficiencies from around 45 percent to more than 50 percent.

In December 1992, the Office of Fossil Energy took one of the first steps in the program with a new \$8.5 million award to a consortium of universities and industrial

sponsors, led by the South Carolina Energy Research and Development Center at Clemson University, to provide research support to the Advanced Turbine Program. The consortium will concentrate on so-called barrier issues (potential generic obstacles), in which university research is most appropriate and applicable to the entire turbine industry.

Four of the Nation's major gas turbine manufacturers—Allison Gas Turbine (Indianapolis, Indiana), General Electric Power Generation (Schenectady, New York), Solar Turbines (San Diego, California), and Westinghouse Electric Corporation's Power Generation Business Unit (Orlando, Florida)—have joined the consortium. In addition, 42 universities agreed to become research performers in the program.

In 1992, DOE awarded contracts to six turbine manufacturers—Westinghouse Electric, United Technologies Corporation (Orlando, Florida), Asea Brown Boveri, General Electric, Solar Turbines, and Allison Gas Turbine—to define system concepts for an advanced utility turbine system. These scoping studies will identify technical issues and resources needed to develop a specific configuration and size for an advanced turbine system. The next step in the turbine development program will be to award contracts to turbine manufacturers to develop market studies and detailed designs of critical components for a natural-gas-fired turbine system. This effort also will include designs of gas turbine systems that utilities, independent power producers, and industrial users can adapt for operation on coal and biomass fuels. The Department awarded four contracts in September 1993.

In May 1993, DOE began circulating to the gas turbine industry a draft of a proposed development plan for the advanced-turbine initiative. By seeking industry comment early in the planning stages, DOE sought to fashion a program that will meet industry's needs and, in turn, attract significant private-sector financial support. In the final plan, issued in August 1993, the Department set a target of at least 30 percent private cost-sharing for the advanced-turbine initiative.

Natural Gas to Liquids

The Natural-Gas-to-Liquids Program focuses on technologies that can economically convert gases to liquid fuels. DOE and its contractors carry out this research through two coordinated activities, one focusing on converting natural gas to liquids, the other on converting light hydrocarbons (primarily methane) derived from such processes as oil refining and coal conversion.

While work is still at the laboratory scale, one particularly promising approach emerged in 1992–1993. The Sun Company, Inc. (Marcus Hook, Pennsylvania), showed the potential for a gas-to-liquid process that would involve biomimetic catalysts. The Sun process directly converts light hydrocarbon gases to alcohol by a catalytic oxidation technique using only molecular oxygen.

In October 1992, DOE selected seven organizations—Altamira Instruments, Inc. (Pittsburgh, Pennsylvania), AMAX Research and Development, Institute of Gas Technology (Chicago, Illinois), Massachusetts Institute of Technology (Boston, Massachusetts), SRI International (Menlo Park, California), Worcester Polytechnic Institute (Worcester, Massachusetts), and the University of Delaware (Newark)—to develop various approaches to converting methane and light hydrocarbons to liquid fuels and chemicals. A separate approach is being developed through a cooperative research and development agreement between Argonne National Laboratory and Amoco Oil Company. This approach will focus on the development of ceramic membranes for the conversion of methane to either synthesis gas or methanol.

OTHER FOSSIL ENERGY TECHNOLOGY ACTIVITIES

Liquefied Gaseous Fuels Spill Test Facility

In 1992–1993, DOE continued to make its Liquefied Gaseous Fuels Spill Test Facility available to industrial users as a national test unit for studying the release of potentially hazardous and toxic gaseous liquids. The facility can reproduce the size and rate of accidental releases that could occur in industrial uses, allowing companies to observe and measure dispersion phenomena, validate models, and design protective measures.

In 1992, the DuPont Chemical Company conducted several hazardous materials (hazmat) response training sessions at the facility, located at the Nevada Test Site. Participants in the training sessions included hazmat "first responder personnel" and other customer personnel who could be involved in the control, mitigation, and cleanup of accidental releases of fuming acid to the environment. Work also continued on a collaborative research and development initiative, begun in 1990, with the Department of Labor's Occupational Safety and Health Administration, the Department of Transportation, the Lawrence

Livermore National Laboratory, and industry. This effort involved testing the effectiveness of commercially available, totally encapsulated, chemical-protective suiting materials when they are exposed to high concentrations of toxic and hazardous chemicals, such as anhydrous hydrogen fluoride.

In preparation for tests scheduled to begin in late 1993, DOE and the Environmental Protection Agency selected and prioritized the first 10 chemicals that will be studied at the facility, as authorized by the Clean Air Act Amendments of 1990.

Great Plains Coal Gasification Plant

On March 23, 1993, the North Dakota State Department of Health issued a revised air pollution control permit to the Great Plains Coal Gasification Plant in Beulah, North Dakota, the Nation's only coal-to-synthetic-natural-gas commercial facility. The permit cleared the way for DOE to open final negotiations to provide financial assistance to the Dakota Gasification Company, the plant owner, to install the necessary sulfur removal equipment to bring the plant into compliance with the permit. Previously, as part of its 1988 sales agreement (which had returned the plant to private-sector ownership following a Federal loan guarantee default by the original owners), DOE had established environmental and reserve trust accounts that could be used for such financial assistance. Dakota Gasification Company proposes to install a flue gas desulfurization unit to meet best available control technology requirements for the facility.

In July 1993, the Department completed a congressionally required report about the Secretary's finding that the proposed environmental modifications are cost effective and are expected to meet the state's environmental emissions requirements. The permit requires that the main stack flue gas desulfurization system be in place by March 1997.

International Program Support

In September 1993, the United States and the Russian Federation negotiated and signed the first memorandum of cooperation in the area of fossil energy under the general framework of the June 1992 science and technology agreement. The memorandum provided a mechanism for

the two governments to undertake cooperative efforts initially in four areas: fossil energy technology and economic assessments; technology research and development; environmental assessment, protection, and remediation techniques and procedures; and development of recommendations on the commercialization and privatization of Russian energy-based facilities. The science and technology agreement is expected to open new exchanges between the United States and the newly independent states of the former Soviet Union and increase opportunities for U.S. business interests.

Also in 1992–1993, DOE renewed international fossil energy agreements with Japan, Korea, and Venezuela after concluding that each offered the United States equitable benefits in terms of information and technology exchange. The same analyses resulted in decisions not to renew agreements with Israel and Norway.

In 1993, DOE completed the 8th year of its participation in the nine-nation, task-shared annex I of the International Energy Agency's implementing agreement on coal combustion science. Under this participation, the United States collected important data on boiler-ash fouling and slagging from a major research boiler, not available in the United States, that Australia provided at no cost. Under another project, all members of the International Energy Agency shared the results of fundamental coal combustion research performed in the United States and Denmark.

Coal and Technology Export Initiatives

In 1992–1993, DOE's Office of Fossil Energy headed two major Pacific Rim trade missions, both of which included a major emphasis on promoting the use of U.S. clean coal technologies in overseas markets. In June 1992, Office of Fossil Energy officials headed a joint Government-industry trade mission to Thailand and Indonesia. The U.S.-Association of Southeast Asian Nations Council for Business and Technology was a partner in this effort. The trip led to a visit by Thai officials to the United States in April 1993 to examine U.S. technology for potential purchases.

In June 1993, DOE led the largest energy trade mission ever to the People's Republic of China. More than 25 U.S. vendors and other companies accompanied the Government on the 3-week series of workshops and briefings to Chinese power officials. The sessions encompassed a broad range of electric-power technologies of commercial interest to the Chinese.

In September 1992, DOE released a call for proposals, opening the second phase of its joint program with the U.S. Agency for International Development to assist Poland in improving air quality. The cooperative international effort, which focuses on the former Polish royal capital of Kraków, is intended to serve as a model for U.S. assistance to the emerging democracies of Eastern Europe. DOE's program opportunity notice outlined how U.S. firms could propose projects for reducing pollution from Kraków's thousands of small coal-burning boilers and furnaces. DOE said it would make up to \$14.5 million available to fund up to 50 percent of the costs of the selected commercial ventures. Technologies proposed for cost sharing must be U.S. technologies or a technology in the public domain. The pollution control systems should be commercial or commercially ready technologies and should have manufacturing capabilities located in Poland. In September 1993, DOE selected nine winning projects. The program is the second DOE-led pollution cleanup effort to be undertaken in Kraków. An earlier project targeted a major coal-burning powerplant on the outskirts of the city for installation of an advanced U.S.-made flue gas scrubbing system.

Education and Research

The Office of Fossil Energy added 52 new university student-teacher research projects to its program through university coal research grants, 26 in 1992 and 26 in 1993. In addition to the normal slate of academic, laboratory-scale coal studies, the 1992 selections included, for the first time, a pilot project to encourage technology transfer from universities to industrial participants. The University of Kentucky and Pennsylvania State University teamed with Consolidation Coal Company (Pittsburgh, Pennsylvania) to develop an improved coal-cleaning technique that will be tested in one of the company's coal preparation plants. In the 1993 competition, DOE selected two projects in a new category to examine ways to capture and dispose of carbon dioxide from coal plants. The two projects, proposed by the University of California at Berkeley and the University of Michigan, will study the use of algae ponds to absorb carbon dioxide.

DOE's Office of Fossil Energy also provided a series of grants to Historically Black Colleges and Universities (HBCUs), awarding eight grants in 1992 and six in 1993. Like the University Coal Research Program, the HBCU Program typically involves at least one student and one teaching professor working together on advanced, feder-

ally sponsored research. In 1992, the Department expanded the Office of Fossil Energy HBCU Program to include all areas of fossil fuel research: coal, oil, natural gas, and oil shale.

In May 1993, DOE held its "First Annual Historically Black Colleges and Universities/Private Sector Fossil Energy Research and Development Technology Transfer Symposium." The 3-day meeting in New Orleans, Louisiana, was intended to increase participation by the Nation's 117 HBCUs in the Fossil Energy Program and to create partnerships between academic institutions and private companies. The symposium also offered an opportunity for researchers receiving Federal grants to report the results of their studies.

NAVAL PETROLEUM AND OIL SHALE RESERVES

The Naval Petroleum and Oil Shale Reserves were established by a series of Executive orders between 1912 and 1924 to provide a future source of liquid fuel for the military. Except for brief periods of production, the reserves were largely inactive until Congress, in response to the Arab oil embargo of 1973, passed the Naval Petroleum Reserves Production Act of 1976 (Public Law 94-258). That act required that the reserves be produced at their maximum efficient rate for a period of 6 years, with the produced hydrocarbons sold at public sale to the highest qualified bidder or transferred to the Strategic Petroleum Reserve. The law also provided the President with discretionary authority to extend production in increments of up to 3 years each if he found such production to be in the national interest. The President formally documents and submits such a determination in a report to Congress 180 days before the end of the current production period. President Reagan exercised the authority to continue production on three occasions (in 1981, 1984, and 1987), and President Bush exercised the authority once (in 1990). On October 7, 1993, President Clinton authorized production at the maximum efficient rates through April 5, 1997.

The Naval Petroleum and Oil Shale Reserves Program consists of three petroleum and three oil shale reserves located in the western United States, all managed by DOE. The locations of the reserves are shown in Figure 3-8. The program is managed by 19 Federal employees in the Washington headquarters office and by an additional 72 Federal and approximately 900 contractor personnel in 2 field offices.

3-8. Map showing locations of Naval Petroleum and Oil Shale Reserves.

As shown in Tables 3-1 through 3-3, the Naval Petroleum and Oil Shale Reserves produced 756 million barrels (103.6 million metric tons) of oil from the three reserves, 1.8 billion cubic feet (0.05 billion cubic meters) of natural gas, and 3.1 billion gallons (11.73 billion liters) of natural gas liquids from 1976 to 1993. During 1992-1993, crude oil, natural gas, and natural gas liquids from the Naval Petroleum and Oil Shale Reserves were sold on the open market through competitive sales (see Chapter 7). Sales for 1992 generated \$473 million and net revenues (after expenses) of \$273 million. Sales for 1993 generated \$440 million and net revenues of \$233 million.

Three times, in April and September 1992 and in March 1993, bids for crude oil from the Naval Petroleum Reserve No. 1 (NPR-1) did not meet a congressionally mandated price test and approximately 20,000 barrels (2,740 metric tons) of oil per day were shipped from NPR-1 to the Strategic Petroleum Reserve. Shipments of crude oil from NPR-1 to the Strategic Petroleum Reserve continued through September 30, 1993.

Table 3-1—Oil production at Naval Petroleum Reserves since open-up, in barrels (metric tons)

Year	NPR-1 ^a		NPR-2 ^b		NPR-3 ^a		Total	
1977 ^c	3,807,974	(521,692)	33,769	(4,626)	147,392	(20,193)	3,989,135	(546,511)
1977	36,999,238	(5,068,896)	142,714	(19,552)	388,861	(53,274)	37,530,813	(5,141,721)
1978	43,485,349	(5,957,493)	128,971	(17,669)	714,467	(97,882)	44,328,787	(6,073,044)
1979	52,639,748	(7,211,645)	121,331	(16,622)	1,540,200	(211,007)	54,301,279	(7,439,275)
1980	58,281,170	(7,984,520)	107,340	(14,705)	1,603,477	(219,676)	59,991,987	(8,218,902)
1981	62,609,584	(8,577,513)	98,606	(13,509)	1,235,835	(169,309)	63,944,025	(8,760,331)
1982	60,698,376	(8,315,678)	97,283	(13,328)	1,144,500	(156,797)	61,940,159	(8,485,802)
1983	57,353,109	(7,857,376)	93,080	(12,752)	1,043,248	(142,925)	58,489,437	(8,013,053)
1984	50,473,675	(6,914,893)	94,179	(12,903)	1,074,799	(147,247)	51,642,653	(7,075,043)
1985	47,683,491	(6,532,638)	92,122	(12,621)	1,061,098	(145,370)	48,836,711	(6,690,629)
1986	42,166,485	(5,776,808)	83,209	(11,400)	1,150,411	(157,606)	43,400,105	(5,945,814)
1987	39,812,627	(5,454,330)	69,663	(9,544)	1,130,402	(154,865)	41,012,692	(5,618,739)
1988	39,316,391	(5,386,346)	67,848	(9,295)	979,279	(134,161)	40,363,518	(5,529,802)
1989	35,214,837	(4,824,433)	63,250	(8,665)	832,643	(114,072)	36,110,730	(4,947,170)
1990	29,945,732	(4,102,565)	70,429	(9,649)	829,492	(113,640)	30,845,653	(4,225,854)
1991	27,154,434	(3,720,157)	70,432	(9,649)	819,886	(112,324)	28,044,752	(3,842,131)
1992	25,442,293	(3,485,594)	70,743	(9,690)	858,433	(117,605)	26,371,469	(3,612,891)
1993	23,878,778	(3,271,393)	116,083	(15,903)	725,765	(99,430)	24,720,626	(3,386,726)
Total	736,963,291	(100,963,970)	1,621,052	(222,082)	17,280,188	(2,367,383)	755,864,531	(103,553,438)

^aTotal reserve production.

^bGovernment's royalty share of production.

^cTransition period covering July 1, 1976, through September 30, 1976, in which the Federal Government changed its fiscal year.

Table 3-2—Natural gas production at Naval Petroleum Reserves since open-up, in thousands of cubic feet (thousands of cubic meters)

Year	NPR-1 ^a		NPR-2 ^b		NPR-3 ^a		NOSR-3 ^c		Total	
1977 ^d	768,125	(21,753)	117,698	(3,333)	7,595	(215)	0		893,418	(25,302)
1977	19,535,104	(553,234)	428,179	(12,126)	179,226	(5,076)	0		20,142,509	(570,436)
1978	34,347,853	(972,731)	379,581	(10,750)	530,145	(15,014)	0		35,257,579	(998,495)
1979	53,310,089	(1,509,742)	361,982	(10,251)	1,269,530	(35,953)	0		54,941,601	(1,555,946)
1980	60,615,227	(1,716,623)	297,787	(8,433)	1,792,477	(50,763)	0		62,705,491	(1,775,820)
1981	101,043,169	(2,861,543)	251,902	(7,134)	2,799,377	(79,278)	0		104,094,448	(2,947,955)
1982	119,485,538	(3,383,830)	274,806	(7,783)	2,774,155	(78,564)	0		122,534,499	(3,470,177)
1983	121,254,625	(3,433,931)	254,306	(7,202)	2,641,015	(74,794)	0		124,149,946	(3,515,926)
1984	128,969,441	(3,652,415)	256,450	(7,263)	2,907,516	(82,341)	0		132,133,407	(3,742,018)
1985	134,745,060	(3,815,980)	268,262	(7,597)	3,033,315	(85,903)	0		138,046,637	(3,909,481)
1986	127,430,198	(3,608,823)	262,488	(7,434)	3,037,404	(86,019)	0		130,730,090	(3,702,276)
1987	125,249,760	(3,547,073)	231,372	(6,552)	3,906,102	(110,621)	0		129,387,234	(3,664,246)
1988	131,379,158	(3,720,658)	225,870	(6,397)	3,923,434	(111,112)	0		135,528,462	(3,838,166)
1989	134,832,380	(3,818,453)	245,979	(6,966)	3,386,559	(95,907)	215,535	(6,104)	138,680,453	(3,927,430)
1990	125,586,458	(3,556,608)	271,653	(7,693)	3,042,560	(86,165)	1,575,731	(44,625)	130,476,402	(3,695,092)
1991	120,664,855	(3,417,229)	274,011	(7,760)	3,210,393	(90,918)	2,079,745	(58,898)	126,229,004	(3,574,805)
1992	114,290,283	(3,236,701)	271,547	(7,690)	2,809,435	(79,563)	1,496,815	(42,419)	118,868,080	(3,366,373)
1993	117,807,470	(3,336,308)	268,140	(7,594)	2,290,891	(64,878)	2,402,108	(68,027)	122,768,609	(3,476,807)
Total	1,771,314,793	(50,163,635)	4,942,013	(139,958)	43,541,129	(1,233,084)	7,769,934	(220,073)	1,827,567,869	(51,756,751)

^aTotal reserve production on a wet basis—includes reinjection, sales, shrinkage, and use.

^bGovernment's royalty share of sales on a dry basis.

^cDepartment of Energy shared from both wholly owned and communitized wells.

^dTransition period covering July 1, 1976, through September 30, 1976, in which the Federal Government changed its fiscal year.

The principal challenge the Naval Petroleum and Oil Shale Reserves Program faces in the years to come—and a challenge that also confronts most other domestic oil producers—is that the most prolific oil-bearing reservoirs are being depleted, costs to extract the oil from the ground are increasing, and market prices for the hydrocarbon products are generally stable or declining. In response to these dynamic technical and economic conditions, the Naval Petroleum and Oil Shale Reserves managers began to identify opportunities to increase recovery efficiencies and decrease costs, and they are continuing to expand these efforts to fully support the President in his call to “reinvent government” to use its resources as efficiently as possible.

In 1993, the Department continued to operate the oil fields in a sound and prudent manner. Activities focused on increasing recovery efficiency and revenues through operation and maintenance of existing wells and facili-

ties, systematic reservoir development through drilling, application of pressure maintenance programs, the pursuit of opportunities to increase profitability, and application of enhanced recovery techniques. Another objective of the program was the control of costs to increase profitability and improve the management of funds. Included in these efforts was the use of \$50 million in carryover funds to construct a facility at Elk Hills, authorized by Congress in 1993, to produce both steam and electricity (cogeneration). Upon completion in 1995, the project will have the dual benefits of reducing daily operating costs and improving the environment by reducing air pollution emissions from other sources that will be taken out of service.

In 1993, Congress (House Report No. 102-626, accompanying the Department of the Interior and Related Agencies Appropriations Act, 1993) requested that the Department of Energy “conduct a study by independent

Table 3-3—Natural gas liquids production at Naval Petroleum Reserves since open-up, in gallons (liters)

Year	NPR-1 ^a		NPR-2 ^b		NPR-3 ^a		Total	
1977 ^c	1,610,910	(6,097,955)	217,401	(822,952)	0		1,828,311	(6,920,907)
1977	34,230,369	(129,575,981)	928,513	(3,514,802)	0		35,158,882	(133,090,784)
1978	56,233,367	(212,866,350)	873,639	(3,307,082)	0		57,107,006	(216,173,432)
1979	96,271,278	(364,426,258)	741,827	(2,808,119)	0		97,013,105	(367,234,378)
1980	132,810,168	(502,740,938)	975,505	(3,692,686)	2,051,043	(7,764,039)	135,836,716	(514,197,663)
1981	185,521,814	(690,919,900)	711,722	(2,694,160)	5,879,785	(22,257,397)	192,113,321	(727,227,686)
1982	236,312,254	(894,538,769)	671,584	(2,542,221)	5,362,798	(20,300,389)	242,346,636	(917,381,379)
1983	237,354,125	(898,482,678)	594,648	(2,250,986)	5,097,751	(19,297,078)	243,046,524	(920,030,742)
1984	228,019,070	(863,145,668)	674,145	(2,551,915)	5,611,463	(21,241,688)	234,304,678	(886,939,271)
1985	249,203,559	(943,337,644)	526,338	(1,992,405)	5,199,346	(19,681,656)	254,929,243	(965,011,706)
1986	230,966,025	(874,301,101)	447,970	(1,695,750)	4,608,239	(17,444,074)	236,022,234	(893,440,925)
1987	230,395,161	(872,140,146)	358,834	(1,358,334)	5,180,707	(19,611,100)	235,934,702	(893,109,580)
1988	236,912,164	(896,809,675)	373,614	(1,414,282)	4,145,823	(15,693,640)	241,431,601	(913,917,597)
1989	231,408,882	(875,977,496)	370,662	(1,403,108)	3,997,150	(15,130,852)	235,776,694	(892,511,455)
1990	197,804,839	(748,772,416)	263,789	(998,550)	3,218,768	(12,184,357)	201,287,396	(761,955,322)
1991	179,236,713	(678,484,446)	257,157	(973,445)	3,068,269	(11,614,656)	182,562,139	(691,072,547)
1992	160,943,799	(609,238,266)	221,049	(836,761)	2,786,886	(10,549,506)	163,951,734	(620,624,533)
1993	155,493,251	(588,605,707)	213,203	(807,061)	2,298,906	(8,702,302)	158,005,360	(598,115,070)
Total	3,080,727,748	(11,650,461,394)	9,421,600	(35,664,619)	58,506,934	(221,472,643)	3,148,656,282	(11,918,954,977)

^cTotal reserve production.^bGovernment's royalty share of production.^cTransition period covering July 1, 1976, through September 30, 1976, in which the Federal Government changed its fiscal year.

experts of development plans, staffing, and organization to optimize the operation of the Reserve.” The experts completed their report, “Evaluation of Operations at Naval Petroleum Reserve No. 1,” which the Secretary sent to Congress on November 2, 1993. The report concluded that the value of the Elk Hills assets could be substantially increased if the Reserve were operated more like a private industry oil company. Specifically, the study determined that the Federal Government, in administering the operation of the Elk Hills oil field, could achieve significant cost savings if its role were reduced by streamlining operations and organizational structures. The study recommended that the Department finalize equity ownership between the Department of Energy and Chevron, its unit partner at Elk Hills; make procurement and personnel authorities an integral part of the operation; no longer utilize the management and operating contract as a mechanism

for field operations; and consider corporatization of the program.

The Naval Petroleum and Oil Shale Reserves embarked on an effort to identify additional hydrocarbon resources on the reserves for future production. In 1993, in cooperation with the U.S. Geological Survey, the Department initiated a project to assess the oil and gas potential of the program's oil shale reserves, which are largely unexplored. These reserves, which total more than 145,000 acres (59,000 hectares) and are located in Colorado and Utah, are favorably situated in oil- and gas-producing regions and are likely to contain significant hydrocarbon deposits. The first phase of the effort, mainly conducted by the U.S. Geological Survey, is to estimate the size of these deposits. This task will continue through the first quarter of 1994.

Naval Petroleum Reserve No. 1

NPR-1, commonly known as Elk Hills, is an oil field covering 47,985 acres (19,419 hectares) in Kern County, California, located 35 miles (56 kilometers) west of Bakersfield. The giant Elk Hills field is the third largest oil field in the lower 48 States in terms of annual oil production and remaining reserves (sixth including Alaskan fields). In 1993, Elk Hills produced an average of more than 65,000 barrels (8,900 metric tons) of oil per day and became only the 14th U.S. oil field to produce a cumulative total of more than 1 billion barrels (137 million metric tons) of oil. In 1992, Elk Hills, at the forefront of developing new technologies in the petroleum production industry, successfully started and completed drilling operations on its fifth and sixth horizontal wells. In 1993, Elk Hills drilled two additional horizontal wells. These wells are now producing approximately 1,000 barrels (137 metric tons) of oil per day. This compares with average production rates of 300 barrels (41 metric tons) of oil per day from conventional vertical wells in the same vicinity.

Most of NPR-1 is operated as a unit under a Unit Plan Contract executed in 1944 between the Federal Government and the Standard Oil Company of California (now Chevron, which is the parent company of Chevron U.S.A., Inc.). This arrangement enables the two unit participants to develop the field on a reservoir basis, rather than on a parcel-by-parcel basis, allowing for more efficient recovery of petroleum resources. Under the contract, each participant's share in unit production of petroleum and costs is in proportion to the volume of commercially productive formations underlying its lands. The Federal Government receives an average of 78 percent of the petroleum products produced from the reserve, and Chevron receives the remainder. Bechtel Petroleum Operations, Inc., is responsible for the management and operation of the field under a 5-year contract that began on August 1, 1985, and that has been extended until July 31, 1995.

During 1992, NPR-1 produced approximately 313 million cubic feet (9 million cubic meters) per day of natural gas and 322 million cubic feet per day of natural gas in 1993. NPR-1 processed the bulk of this gas to remove natural gas liquids, which the Department then competitively sold on the open market, with the bulk of the dry gas reinjected into underground formations to maintain pressure on the oil-bearing reservoirs. The daily average yield to the Government from the gas processing was 152,000 gallons (575,000 liters) of natural gasoline, 155,000 gallons (587,000 liters) of propane, 110,000 gallons (416,000 liters) of mixed butane, and 24,000 gallons

(91,000 liters) of isobutane. The daily average yield to the government from the gas processing in 1993 was 150,000 gallons of natural gasoline, 144,000 gallons of propane, 102,000 gallons of mixed butane, and 30,000 gallons of isobutane. The government's sales and other Naval Petroleum Reserve No.1 revenues for 1992 totaled more than \$451 million and more than \$419 million in 1993.

Figures 3-9 and 3-10 show two views of NPR-1. In the former, an employee inspects the gas-line pig launcher, while the latter shows the typical tank setting. In order to protect the environment from potential tank spills, all settings had earthen berms replaced with concrete-filled corrugated pipe berms.

3-9. Inspecting the gas-line pig launcher at NPR-1.

3-10. Berm tank setting at NPR-1. All tank settings had earthen berms replaced with concrete-filled corrugated pipe berms.

In 1992, the Government initiated a number of projects to protect and enhance environmental quality at NPR-1. Included in these is a vanpool program that began in August 1992, with 19 vans fueled by compressed natural gas. Besides improving employee safety and economics, this program resulted in significant reductions in air pollution emissions from vehicles that were no longer used for employee transportation. NPR-1 received the Regional Award of Merit for Transportation from the Kern Council of Governments and a commendation from the San Joaquin Valley Air Pollution Control Board for this project. In 1993, NPR-1 expanded the vanpool program and completed construction of an onsite refueling station that permits the vehicles to be fueled from the reserve's production.

Among other environmental protection and safety projects undertaken in 1992 and 1993, NPR-1 worked to support the Secretary's "tiger team" assessment initiative. On June 27, 1989, the Secretary announced a 10-point program to strengthen safety, environmental protection, and waste management activities at DOE facilities and established independent tiger teams for compliance assessments at these sites. DOE performed a tiger team assessment of NPR-1 in late 1991, and NPR-1 completed a final corrective action plan that addressed work needed to mitigate the 245 findings identified in the assessment in April 1993. Projects to address many of the deficiencies began immediately after the assessment, but closure of all the findings will take a number of years. By September 1993, approximately 53 percent of all action plan milestones had been completed, which resulted in the completion and closing of the 245 findings.

Naval Petroleum Reserve No. 2

Naval Petroleum Reserve No. 2 (NPR-2), located at Buena Vista Hills adjacent to NPR-1, has been leased continuously for production since the early 1920s. Through 1993, NPR-2 produced more than 649 million barrels (88,913,000 million metric tons) of oil, reducing recoverable reserves to an estimated 4 million barrels (548,000 metric tons). Production now comes predominantly from stripper wells, which individually produce less than 10 barrels (1.4 metric tons) of oil per day. The Government receives royalties from the NPR-2 leases, which resulted in revenues of approximately \$2.1 million in 1992 and \$2.6 million in 1993. The Government's role at this reserve generally is limited to production accounting and lease surveillance.

Naval Petroleum Reserve No. 3

Naval Petroleum Reserve No. 3 (NPR-3), the Teapot Dome field 35 miles (56 kilometers) north of Casper, Wyoming, consists of 9,481 acres (3,837 hectares) owned and managed by the Government. During 1993, total production averaged 1,988 barrels (272.35 metric tons) of oil per day. Revenues from the sale of oil and liquid products totaled \$18 million in 1992 and \$14 million in 1993.

NPR-3 is an aging stripper field and requires proactive management of petroleum production to maintain a profitable operation. The initial success of the Shannon Steamflood Project, as well as drilling and well maintenance programs at NPR-3, has slowed the production decline that had been continuing for many years. John Brown Engineers and Constructors, Inc., formerly Lawrence-Allison and Associates West, Inc., (Houston, Texas) had been the management and operating contractor for NPR-3 since September 1981. It began a second 5-year contract on October 1, 1986, which was extended through September 30, 1992. DOE recompeted the 5-year contract and selected FD Services, Inc. (a subsidiary of Fluor Daniel, Inc., of Greenville, South Carolina) the current contractor, to manage and operate NPR-3 effective October 1, 1992.

Currently, NPR-3 produces oil and gas from more than 300 wells. NPR-3 processes two grades of crude oil and then sells them competitively. Customers or purchasers transport sweet crude from the reserve through a pipeline owned by Amoco Oil Company, whereas they use trucks to transport the much smaller volumes of sour crude. An onsite plant processes natural gas using low-temperature separation to extract salable liquid products. NPR-3 then compresses the dry gas for reinjection or uses it for field fuel requirements. NPR-3 carries out pressure maintenance by water or gas injection in three reservoirs, and it has developed a steam-drive enhanced oil recovery project. In 1992, NPR-3 drilled 12 producing wells and 10 injection wells in the new pattern from the fifth steam generator. Figure 3-11 pictures Drill Rig No. 3 88-2-SX-3. In October 1992, the fifth steam generator began injection. During 1993, NPR-3 drilled injection and production wells in two additional patterns. NPR-3 conducts drilling selectively, based on reservoir analyses that identify undrained areas or favorable exploratory targets. At the end of 1993, production from 180 producing wells in the steamflooded area was averaging more than 800 barrels (110 metric tons) of oil per day.

3-11. NPR-3 Drill Rig No. 3 88-2-SX-3.

In response to the 10-point initiative introduced by the former Secretary in 1989, a tiger team held an environment, safety, and health assessment at the Naval Petroleum and Oil Shale Reserves in Colorado, Utah, and Wyoming from June 15 to July 22, 1992. In August 1993, the Secretary approved NPR-3's final corrective action plan for the 196 findings, none of which presented an immediate risk to public health or to the environment. By September 1993, a significant portion of the corrective actions had already been implemented, or was in the process of being implemented.

Naval Oil Shale Reserves

The three Naval Oil Shale Reserves (NOSRs) were created to provide emergency reserves of liquid fuel for the military. Because oil shale is not competitive with conventional sources of oil, these reserves have not yet been developed. Oil production at the Naval Oil Shale reserves has been limited to that associated with oil shale research at the Anvil Points facility (now decommissioned and removed) located on Naval Oil Shale Reserve No. 3 (NOSR-3) in Colorado.

NOSR-1 and NOSR-3 are two adjacent oil shale reserves of 40,760 and 14,130 acres (16,510 and 5,720 hectares), respectively, located about 8 miles (13 kilometers) west of Rifle, Colorado, in Garfield County. Except for oil shale claims to about 600 acres (243 hectares) of NOSR-1, the Government owns all lands and minerals at NOSR-1 and NOSR-3. The Government estimates NOSR-1 to have more than 18 billion barrels (2.5 billion

metric tons) of shale oil in place, with approximately 2.5 billion barrels (340 million metric tons) of oil recoverable from shale rated at 30 gallons or greater per ton (126 liters or more per metric ton) of shale. NOSR-3 has no commercial oil shale, but was set aside to gain closer access to the Colorado River and to provide working space in support of NOSR-1 activities. In 1982, the Department completed a 5-year predevelopment plan to assess the oil shale resources and to analyze factors related to the development of NOSR-1 when appropriate. The data indicate that, while production is not economically feasible today, the potential exists for production of 200,000 barrels (27,400 metric tons) of oil per day for more than 30 years.

NOSR-2, in northeastern Utah, consists of 90,440 acres (36,600 hectares) and is estimated to contain almost 4 billion barrels (548 million metric tons) of shale oil in place. No estimate of recoverable reserves has yet been made, but none of the shale oil is economically recoverable at today's oil prices. Seismic surveys conducted at NOSR-2 in 1981, which TRW evaluated in 1982, revealed the presence of several promising geological structures in which oil and gas resources may be trapped; however, to date, no budget authority has been provided for exploration on NOSR-2 or for the protection of the reserves through direct Government development, nor has any proposal been made to allow leasing by private industry.

During the mid-1980s, private developers began to complete natural gas wells on private lands and in fields common to NOSR-1 and NOSR-3. To fulfill the statutory requirement to protect gas under the NOSR land from drainage, the Department developed a protection plan providing for the communitization of wells with private owners and the drilling of offset wells on the reserves.

In communitization, the Government by agreement shares in the production and costs from wells drilled near the boundary of the NOSRs. This is identical to the standard petroleum industry practice for sections of land having multiple ownership, where the owners agree to develop the mineral resources jointly and to share the costs and production based on percentage ownership of the surface area. Under standard communitization agreements, each well is operated as a unit, and development costs and hydrocarbon production are shared between the unit partners, with the actual percentage of ownership based on the amount of each partner's surface land contained in the unit. Tracts are pooled under communitization agreements when the separate tracts cannot be developed and operated independently in conformity with state well-spacing requirements or established well development programs.

In addition to communitization of privately drilled wells, it is necessary for the Government to drill its own gas wells inside the reserves' boundaries to directly offset privately drilled wells on private lands. While most of these wells are entirely Government owned and operated, some Government-drilled offset wells may be communitized with adjacent private property owners or lessees.

Through September 1993, private industry drilled 102 wells within 1 mile (1.6 kilometers) of NOSR boundaries. Private industry has also drilled thirteen nonproducing commercial wells, which either were plugged and abandoned or have not been produced because of their marginal production or distance from a pipeline.

DOE has entered communitization agreements for 20 wells that are operated by private interests, but 2 of the 20 wells have been deferred to early fiscal year 1994. To mitigate drainage and migration of natural gas to the commercial producers, DOE has drilled 15 offset wells that are owned entirely by the Government and 6 wells that are communitized with adjacent private landowners or leaseholders and operated by the Department. This 39-well program has prevented significant drainage. The Department plans four wells for drainage protection for 1994.

Exploration of optimal methods of financing development and of transporting and marketing NOSR natural gas will continue to be the dominant theme of the mid-1990s.

STRATEGIC PETROLEUM RESERVE

New Legislation

In October 1992, President Bush signed into law the Energy Policy Act of 1992 (Public Law 102-486), which contains the following provisions:

1. New criteria for SPR drawdown in emergency situations resulting in supply reduction of significant scope and duration, coupled with a severe price increase likely to cause a major adverse impact on the national economy
2. Expansion to 1 billion barrels (137 million metric tons)

3. Advance payments for petroleum products not owned by the United States, for storage in unused reserve facilities; or for crude oil either owned or not owned by the United States, for storage in nonreserve facilities
4. Presidential discretionary authority to acquire domestic stripper-well oil at competitive prices
5. Amended eligibility criteria for a regional petroleum reserve
6. A study of the unique vulnerabilities of insular areas to an oil supply disruption
7. A study about the use of futures and options contracts to reduce the cost of purchasing petroleum by Government and private entities

Facilities Development

In 1992, the Department decommissioned for sale the smallest site, Sulphur Mines in Louisiana, with a capacity of 25 million barrels (3.4 million metric tons), and transferred its oil to the Big Hill site in Texas. On January 15, 1993, the Department signed a contract of sale for \$400,000 with PPG Industries, Inc., formerly Pittsburgh Plate Glass (Pittsburgh, Pennsylvania). The sale occurred May 10, 1993.

Table 3-4 shows the amounts of crude oil inventory in storage at the five existing sites, as well as in tanks and pipelines, as of September 30, 1993. Figure 3-12 is a map

3-12. Map showing locations of storage and other facilities of the Strategic Petroleum Reserve.

Table 3-4—Amounts of crude oil in Strategic Petroleum Reserve storage sites as of September 30, 1993, in millions of barrels (millions of metric tons)

Strategic Petroleum Reserve storage site	Storage capacity		Current inventory		Capacity available for fill	
Bryan Mound	226	(35.9)	217	(34.4)	9	(1.4)
West Hackberry	219	(34.8)	205	(32.6)	14	(2.2)
Weeks Island	73	(11.6)	72	(11.4)	1	(0.2)
Bayou Choctaw	72	(11.4)	52	(8.2)	20	(3.1)
Big Hill	160	(25.4)	37	(5.9)	123	(19.6)
Subtotal	750	(119.1)	583	(92.5)	167	(26.5)
Tanks and pipelines	—	—	3	(0.4)	—	—
Total	750	(119.1)	586	(92.9)	167	(26.5)

showing the locations of storage and other facilities of the Strategic Petroleum Reserve.

Oil Acquisition

During 1992, DOE acquired approximately 7.9 million barrels (1.1 million metric tons) of crude oil for SPR. Of that amount, the Defense Fuel Supply Center, acting as a purchasing agent for the Department under an interagency agreement, bought 3.6 million barrels (493,000 metric tons). Under this arrangement, the Defense Fuel Supply Center purchases the oil under an open, continuous solicitation for competitive offers. The Defense Fuel Supply Center purchased the balance of oil (4.3 million barrels, or 589,000 metric tons) from NPR-1 in California. Through September 30, 1993, DOE acquired approximately 15.1 million barrels (2.1 million metric tons) of crude oil for SPR. The Department purchased 5.4 million barrels (740,000 metric tons) through the Defense Fuel Supply Center and 9.7 million barrels (1.3 million metric tons) from NPR-1 in California.

Moreover, the Department of Defense Appropriation Act, 1993 (Public Law 102-396) provided DOE with \$125.6 million to purchase crude oil for the Department of Defense. The legislation allows DOE to transfer up to \$700,000 to the SPR account to pay for the costs of operations and maintenance associated with additional oil acquisition and storage. The outlay limit in Public Law 102-381 and the net resources provided under Public Law 102-396 provide \$262 million for oil acquisition in 1993.

Drawdown and Distribution

SPR has an initial drawdown rate of 3.5 million barrels (480,000 metric tons) per day and a distribution capability of 4.1 million barrels (562,000 metric tons) per day for 90 days. The crude oil has been commingled in storage and can be sold in eight distinct crude oil streams.

Competitive Sales Procedures

The most recent edition of the Standard Sales Provisions was published in the *Federal Register* on December 11, 1992. This version revises the previous Standard Sales Provisions published in June 1988 and incorporates improvements identified during the 1990 test-sale and 1991 Desert Storm drawdown.

Drawdown Tests

During 1992, five tests of site drawdown systems were conducted to demonstrate drawdown and distribution capabilities:

1. *June 30, 1992:* 128,000 barrels (17,500 metric tons) from the Big Hill site were delivered to Sun Terminal, demonstrating a sustained rate capability of 408,000 barrels (56,000 metric tons) per day

2. *September 3, 1992:* 223,000 barrels (30,500 metric tons) from the Bryan Mound site were delivered simultaneously to Atlantic Richfield and Phillips terminals, demonstrating a combined rate capability of 1.16 million barrels (159,000 metric tons) per day
3. *September 19, 1992:* 77,000 barrels (10,500 metric tons) from the Weeks Island site were delivered to St. James Terminal, demonstrating a sustained rate capability of 643,000 barrels (88,000 metric tons) per day
4. *November 6–8, 1992:* 703,000 barrels (100,000 metric tons) from Weeks Island were delivered to St. James Terminal (Figure 3–13), achieving a maximum instantaneous rate of 427,000 barrels (58,500 metric tons) per day
5. *December 11, 1992:* 64,000 barrels (9,000 metric tons) from the Bayou Choctaw site, using its recovery drawdown system, were delivered to St. James Terminal, demonstrating a rate capability of 480,000 barrels (66,000 metric tons) per day

During the period from August 2 to September 17, 1993, SPR conducted a drawdown training exercise called SPRITE–VII. This exercise involved the entire SPR program, including contractors, in the performance of the various functions, excluding the actual movement of oil, associated with conducting a drawdown and sale of SPR crude oil in the event of a severe energy emergency. SPRITE–VII was successful in meeting its training objectives and enhancing the reserve's readiness to meet a drawdown situation.

Elimination of Allocation Regulations

During 1992, the Department eliminated regulations entitled "Strategic Petroleum Reserve Crude Oil Allocation" (title 10, part 200, of the Code of Federal Regulations) because of the expiration of the Emergency Petroleum Allocation Act.

Expansion of the Reserve

The Energy Policy and Conservation Act (EPCA) Amendments of 1990 (Public Law 101–383) required an SPR Plan Amendment by September 15, 1992, detailing the Department's plans for design, construction, and acquisi-

3–13. Crude oil pump at St. James Terminal.

tion of storage facilities to achieve 1 billion barrels (137 million metric tons). In May 1991, the Department announced its intent to prepare an environmental impact statement to address the environmental effects of expanding the capacity of the reserve.

The Department issued a draft environmental impact statement in October 1992, addressing five candidate sites: Big Hill and Stratton Ridge in Texas, Weeks Island and Côte Blanche in Louisiana, and Richton in Mississippi. The Department held public hearings in December 1992 and extended the comment period through July 20, 1993.

In January 1993, the Department received comments on the draft environmental impact statement requesting further consideration of an alternative means of brine disposal. To ensure that all reasonable alternatives have been considered, the Department plans to issue a supplement to the draft environmental impact statement for the Richton, Mississippi, and Côte Blanche, Louisiana, sites to reflect the proposed alternative methods of brine disposal. In June 1993, the Department issued the supplement, which was followed by public comment and consideration of comments. The Department expects to address the issuance of the final draft environmental impact statement, the Record of Decision, and the SPR Plan Amendment as part of the EPCA reauthorization in the fall of 1994.

Environment, Safety, and Health

The Department's Environment, Safety, and Health tiger team conducted an assessment of SPR from March 9 through April 10, 1992. The scope of the assessment in-

cluded five operational sites used for crude oil storage and handling, the decommissioned crude oil storage site at Sulphur Mines, the Project Management Office, and the Program Office in Washington, D.C. In December 1992, SPR submitted for departmental approval a final Corrective Action Plan, prepared in response to the tiger team's assessment, which has been incorporated into the Environmental, Safety, and Health 5-year plan.

Overall, the tiger team concluded that the reserve's activities do not pose any undue environmental, safety, and health risks; that employees are motivated to work safely and perform their jobs correctly; and that an environmental, safety, and health culture is being established throughout the reserve.

New Management and Operating Contractor

On November 18, 1992, the Assistant Secretary for Fossil Energy selected DynMcDermott Petroleum Operations Company (New Orleans, Louisiana) to succeed Boeing Petroleum Services, Inc. (New Orleans, Louisiana), and to provide management and operating services for 5 years under an Award-Fee Contract, commencing April 1, 1993.

FUELS PROGRAMS

The Office of Fuels Programs (OFP) within the Office of Fossil Energy administers the natural gas import and export licensing program, pursuant to the Natural Gas Act of 1938; the electricity export licensing activities, in accordance with the Federal Power Act of 1935; the issuance of Presidential permits for construction and use of transmission facilities for international exchanges of electricity, pursuant to Executive Order 12038; and certain provisions of the Powerplant and Industrial Fuel Use Act of 1978.

OFP monitors international natural gas and electricity trade as a part of its regulatory responsibilities. OFP requires natural gas companies and electric utilities to file trade information for the following reasons:

1. To ensure that importers and exporters are acting in compliance with their authorizations;
2. To monitor the expanding North American energy market for purposes of performing market and contract analyses;

3. To improve the capability of industry and government to respond to emergency energy supply disruptions; and
4. To monitor the effects of the North American Free Trade Agreement (NAFTA). Natural gas import and export data are collected on a quarterly basis and are made available in the Natural Gas Import and Export Quarterly Report.

OFP collects and reports the electric data on an annual basis. This information is used extensively throughout industry and government and is available on a publicly accessible OFP electronic bulletin board (202-586-7853).

Natural Gas Import and Export Program

Applications to import and export natural gas reached a historic level in 1992 (Figure 3-14). OFP received 162 applications and issued 201 final authorizations during this year. In 1993, the caseload level nearly matched the 1992 level. OFP received 150 applications and issued 167 final authorizations. With the recent passage of NAFTA, OFP expects the caseload level to increase slightly in 1994.

During 1992, natural gas imports reached historic highs in terms of absolute volumes and as a percentage of U.S. market share. Net Canadian natural gas imports increased to 2 trillion cubic feet (57 billion cubic meters (bcm)) and accounted for about 10 percent of total U.S. natural gas consumption, as compared to an 8.5 percent market share in 1991. In 1992, the U.S. exported about 243 billion cubic feet (bcf) (6.9 bcm) of natural gas, representing an 88-percent increase over the 1991 export level of 129 bcf (3.7 bcm). Figure 3-15 depicts natural gas imports and exports from 1986 through 1992.

During the first 9 months of 1993, the United States imported 1706 bcf (48 bcm) of natural gas. This is about an 11-percent increase over the import level during the first 9 months of 1992 (1542 bcf or 44 bcm). The United States exported 115 bcf (3 bcm) of natural gas during this time period, a 36-percent decrease compared to the 1992 export level of 181 bcf (5 bcm). Imports of Algerian liquefied natural gas increased by 135 percent during this time period. While the amount of natural gas exports is expected to decrease during 1994, most forecasters expect that natural gas imports will continue to grow and play an increasingly important role in providing a reliable, relatively clean-burning source of energy to the United States.

3-14. Applications and orders for natural gas, 1977-93.

Electricity Export Program

During 1993, OFP processed 22 requests for electricity exports or Presidential permits. Five electricity exports were authorized or amended and one permit for facility construction was issued. In recent years, as the quantity of electricity imports and the capacity of new international transmission lines have increased, the geographic and technical scope of reliability impacts and the number of contentious environmental issues have increased proportionally. This has dramatically increased the analytical work required to process each request, as well as significantly increased the administrative work required to handle an ever-increasing number of protests and intervenors.

Figure 3-16 illustrates the level of electricity trade between the United States and Canada and Mexico from 1973 through 1992. As of January 1994, OFP's caseload consisted of 9 permit applications and 7 export authorization requests. During 1994, the office estimates an additional 5 permit applications and 5 export authorization requests.

Fuels Conversion Program

The Powerplant and Industrial Fuel Use Act of 1978 prohibited natural gas and petroleum use in certain new facilities for electricity generation and industrial use. On May 21, 1987 (Public Law 100-42), the act was amended to exempt nonutility installations and certain other utility facilities from prohibitions against the use of natural gas and petroleum in new fuel-burning facilities. As a result, oil or gas can be used for electricity generation when the fuel is economically competitive.

Present general requirements under the act state that no new electric powerplant may be constructed or operated as a baseload powerplant without the capability to use coal or another alternate fuel as a primary energy source. The act further allows the owner or operator of any new electric baseload powerplant to certify that the facility can use coal or an alternate fuel. Following enactment of the amendment, the number of applications requesting exemptions from the prohibitions of the act dropped from 139 in 1986 to 7 in 1988, and to zero in the years since 1988. During 1993, OFP processed one application for rescission of a prohibition order and 18 self-certifications of alternate-fuel capability, representing 2,323 megawatts of capacity.

3-15. Natural gas import and export activity, 1986-92.

3-16. Electricity import and export transactions with Canada and Mexico, 1973-92.

CHAPTER 4

NUCLEAR ENERGY

INTRODUCTION

Nuclear power plays an important role in the current energy mix of the United States. In 1992, 110 nuclear powerplants provided 22 percent of the Nation's electricity (Figure 4-1 shows the locations of these plants). Consequently, it is likely that for the foreseeable future, nuclear power will remain an important option for meeting the Nation's demand for electricity.

DOE's civilian reactor development activities focus on programs that are synergistic with the existing nuclear industry and can potentially contribute to resolution of the industry's long-term challenges. In 1992 and 1993, the Office of Nuclear Energy worked to develop new technologies for nuclear power and to encourage a stable and predictable regulatory and licensing environment for nuclear power. The main goal is to ensure that nuclear power remains an available option should the private sector decide to invest further in nuclear powerplants.

If nuclear power is to remain a viable energy supply option, nuclear waste must be safely and economically managed. DOE recognizes that progress on the waste disposal issue is one of the critical aspects to public acceptance of any future nuclear powerplants. Thus, during 1992 and 1993, the Office of Nuclear Energy conducted a program to evaluate the technical and economic feasibility of a technology that would complement the geologic repository for long-term storage of high-level nuclear waste (see Chapter 5) by assisting in responsible management of high-level nuclear waste.

DOE's nuclear energy programs also include the Isotope Production and Distribution Program, which provides radioactive and stable isotopes and associated services to

domestic and international markets. Ultimate applications for isotopes include health care, basic research, industry, agriculture, and education.

In addition, DOE is participating, through its nuclear energy programs, in initiatives with Eastern European countries and the Newly Independent States of the former Soviet Union. These initiatives constitute a set of integrated activities to protect public health and the environment in this region by improving the operating procedures of existing nuclear powerplants and reducing the chance of nuclear accidents.

Another element of DOE's nuclear energy program is the production of space nuclear electric power sources and propulsion systems when there are identified needs for such systems. The radioisotope thermoelectric generators for NASA's Cassini mission are an example of such a need. Nuclear power supplies developed by DOE are operating on the *Galileo* spacecraft, which is en route to Jupiter, and on the *Ulysses* spacecraft, which is continuing its mission to the Sun.

LIGHT-WATER REACTORS

DOE's Light-Water Reactor Program provides support in two areas: license renewals for operating light-water reactors (LWRs) and development of advanced light-water reactors (ALWRs). ALWRs feature major improvements over the current generation of LWRs—simplified, improved, and standardized designs; enhanced safety, reliability, and construction; and simplified plant operation. The four standard ALWR plant designs being developed feature extensive use of modular components to reduce

4-1. Locations of commercial nuclear powerplants in the United States as of September 1993.

construction time and cost, and two of these designs also feature passive safety systems.

The primary goal of the ALWR Program is to assist utility companies developing the four standard ALWR powerplant designs and to help obtain Nuclear Regulatory Commission (NRC) certification of those designs by the late 1990s. The strategy and schedule are driven by the time utilities will need to order and build new plants to meet projected demand. Recent projections indicate that, even after reducing demand through aggressive conservation measures, the Nation will still need 100 to 200 gigawatts of additional system capacity by 2010.

Current Light-Water Reactors

Between 2000 and 2015, the 40-year licenses of nearly 50 operating nuclear units will expire. By 2030, all but one of the licenses of operating plants will have expired. Studies

show that by renewing the licenses of these plants, approximately 100 gigawatts of capacity replacements could be deferred for 20 years. The Department is confident that most of these plants can continue to operate safely and efficiently for up to 20 years beyond their current licenses and is working with the NRC and industry to develop this option for utilities to consider as part of their integrated resource planning.

Advanced Light-Water Reactors

The ALWR Program is a cooperative, cost-shared undertaking with industry, reactor manufacturers, and architect-engineering firms. One major effort aims to achieve certification of designs for two large (1,250 to 1,350 megawatts-electric) ALWR plants under the new NRC licensing procedure (10 CFR Part 52). These are General Electric's Advanced Boiling-Water Reactor and ABB

Combustion Engineering's System 80+ pressurized-water reactor. NRC certification of these plants is scheduled for 1996.

A second major ALWR effort is devoted to designing and achieving certification of two simplified, passive plants of intermediate size (600 megawatts-electric): the Westinghouse AP600 pressurized-water reactor and the General Electric Simplified Boiling-Water Reactor. These designs are targeted for certification during 1997. Initial safety analysis reports were submitted to the NRC in the summer of 1992, and design work and preparation of the standard safety analysis reports are proceeding aggressively. The two plants feature passive safety systems and greatly simplified designs that will enhance plant safety and reliability. Their extensive use of modular components and prefabricated materials will significantly reduce plant construction time and associated costs. Further, the smaller size of, and the lower capital investment required for, these powerplants will offer utilities an attractive option in providing reliable, safe electric power.

Certification of all four designs (two large and two intermediate-sized) will provide opportunities for new plant construction orders later in the 1990s.

The Commercial Standardization Program is another major part of the ALWR Program. This cooperative, cost-shared undertaking focuses on completing first-of-a-kind engineering for selected ALWR design concepts. Each of these design concepts will be applicable to all plants within the same standardized family. The designs will go beyond the level of detail required for certification and provide the cost and schedule certainty that will allow the marketplace to begin to order new nuclear plants later in the 1990s.

The ALWR Early Site Permit Program component of the ALWR Program is working to assess and demonstrate the NRC's early site permit regulations (10 CFR Part 52), that is, regulations for licensing and reserving a site before the need for it arises. The program consists of three phases: assessment of current regulatory requirements for nuclear plant siting, development of the site selection process, and preparation and submittal of an application for an early site permit to the NRC. In 1992 and 1993, phases I and II of this program were completed.

Current and Advanced Light-Water Reactor Safety

DOE is conducting studies in support of the Electric Power Research Institute's development of generic criteria to ensure the safe performance of ALWRs in the event of

severe accidents. These studies include technical issues associated with reactor accidents, such as cooling of molten core debris and quantification of radionuclide releases in various types of accidents. Technology, experience, and research derived from the earlier Three Mile Island Program provide additional focus to these studies. Several issues are being addressed through participation in international programs sponsored either by the Organization for Economic Cooperation and Development's Nuclear Energy Agency or by international consortia formed specifically for studies and analyses of specific nuclear safety issues. In terms of research data, this approach provides a high return on the relatively few dollars invested.

ADVANCED REACTOR RESEARCH AND DEVELOPMENT

DOE continued during 1992 and 1993 to pursue research and development (R&D), though at a somewhat reduced effort, on advanced nuclear systems that offer the potential for significant advancements in production, economics, safety, environmental protection, and waste management.

Modular High-Temperature Gas-Cooled Reactor

The Modular High-Temperature Gas-Cooled Reactor (MHTGR) Program is a cooperative effort that has involved the Government, the private sector, and international organizations. Its design, research, technology development, and testing activities aim to establish the MHTGR as a cost- and risk-competitive option for a broad range of powerplant owners and operators. Activities have included developing and assessing design requirements and providing overall program development support. DOE is working to ensure that all appropriate technology from the recently closed out New Production Reactor Program is transferred to the MHTGR Program.

MHTGR Program activities concentrate on licensing, fuel technology development, and reactor design. Licensing activities include interacting with the NRC to resolve key issues, such as the radionuclide source term and the acceptability of a vented low-pressure containment system, and supporting the effort to issue a final preapplication safety evaluation report by the end of 1994.

Efforts to define and evaluate the concept of a helium turbine for the power conversion system are also under way. This concept is attractive because of its potential high thermal efficiency, which could provide both economic and environmental benefits by reducing the quantity of fuel waste and heat rejection. Operation at higher temperatures could also provide opportunities for process heat applications. In addition, economies in capital and operating costs could be derived from eliminating the steam generator, steam turbine, and associated systems.

Advanced Liquid-Metal Reactors

The Advanced Liquid-Metal Reactor (ALMR) Program and its associated Actinide Recycle Program are directed toward the development of a technology that can contribute to enhancing the quality of the environment, managing radioactive waste, and extending valuable resources. Program activities consist of three major components:

1. *Fuel cycle:* Argonne National Laboratory (ANL) R&D on an integral fast reactor (IFR) system for the metal fuel cycle associated with an ALMR
2. *LWR actinide recycle:* ANL R&D on applying the fuel cycle processing capability of the IFR system to LWR spent fuel
3. *Reactor design:* General Electric Company design of the ALMR—including the ability to consume LWR spent fuel—for the Department under the trademark PRISM (Power Reactor, Innovative Small Module)

The main efforts of the IFR Program and related design support activities are directed toward developing and demonstrating the ALMR's closed metal fuel cycle. The rationale for pursuing this technology lies in its potential to meet the reliability, waste management, safety, nonproliferation, and economic criteria necessary for commercialization of ALMR technology.

The IFR Program includes R&D efforts in the areas of pyroprocess development, fuel performance, core design, waste-stream management, safety, licensing, and actinide recycling. Goals in this area include evaluating the performance of metallic fuels under normal operating and accident conditions, developing and demonstrating the new electrorefining process, confirming the advantages of passive safety, and verifying total fuel-cycle economics.

Electrorefining experiments designed to establish the feasibility of pyroprocessing have been carried out on a 10-kilogram engineering scale at ANL, and successful demonstration of anodic dissolution indicates that the desired pyroprocessing rates can be achieved. Efforts to establish the chemistry of actinide separation in the IFR's fuel cycle are also meeting success.

Feasibility studies of extending the pyrochemical process to extract actinides from spent LWR fuel have identified several promising options, and the LWR Actinide Recycle Program continues to develop these options. Since laboratory-scale testing of LWR actinide recycle technologies began in 1990, four promising pyrometallurgical processes have been demonstrated, and a single reference process was selected in 1993. This process uses lithium to reduce the oxide fuel to metal before refining. With continuing success, these studies could lead to improvements in long-term waste management. The National Academy of Sciences is studying the application of separation and transmutation technologies to commercial spent fuel and the potential impact of their use on the management of high-level radioactive waste. This study is scheduled for publication in 1994.

In 1994, IFR and LWR actinide recycle development activities will be integrated into a single Actinide Recycle Program whose objective is to permit a technical and economic feasibility evaluation of the technology to contribute to waste management while economically providing nuclear power.

ALMR design activities include tasks related to plant design, safety, licensing, components, and cost. A major accomplishment of the ALMR design program was NRC issuance of the preapplication safety evaluation report for the advanced conceptual design in early 1994.

ISOTOPE PRODUCTION AND DISTRIBUTION

The Isotope Production and Distribution Program produces and markets radioactive and stable isotope products and associated services to a wide, varied domestic and international market. These products and services originate from DOE production and research facilities, where radioisotopes are produced in reactors and accelerators and are separated from fission products. Stable isotopes are also separated at DOE facilities from naturally occurring chemical elements. Despite the program's modest size, its con-

tributions to people's health and the country's competitiveness is significant. Thousands of medical procedures performed each day use radioisotopes. Moreover, research related to medical and other isotope applications can affect health, industrial safety, and competitiveness. The ultimate applications of isotope products include medical research, diagnosis, and therapy; basic and applied research and education; industrial research and manufacturing; and agriculture and food preservation.

In 1992, a joint DOE-industry study verified the feasibility of producing molybdenum-99 and related medical isotopes in DOE facilities previously used for defense programs, and plans to start production using this approach were developed. The goal of this initiative is to establish an indigenous U.S. source of supply for molybdenum-99, iodine-131, xenon-133, and iodine-125, which are used in more than 30,000 medical, diagnostic, and therapeutic procedures each day in the United States. Production of molybdenum-99 in the Omega West Reactor at Los Alamos National Laboratory was to begin by mid-1993, but reactor operations had to be suspended because of a water leak in the cooling system in early 1993. Thus, the molybdenum-99 initiative has been delayed until DOE can either repair and restart the reactor or select an alternate production source.

To better serve their customers and understand market demands and future trends, Isotope Production and Distribution Program representatives attend and participate in studies, conferences, and symposia related to isotopes and discuss current and future needs with the Society of Nuclear Medicine, the American College of Nuclear Physicians, and other associations. In addition, program representatives continue to work with the DOE Office of Energy Research and the Society of Nuclear Medicine on the proposed National Biomedical Tracer Facility. The three parties have developed a position favoring an early, substantive project definition study and have advised Congress accordingly.

The Isotope Production and Distribution Program has the operating requirements and characteristics of any ongoing business concern, including the need to minimize expenses, generate revenues, and respond to market needs. The Department is evaluating program restructuring options derived from an Arthur Andersen & Company management study published in March 1993 and from internal program assessment. The goal is to make the program efficient and sustainable, thus ensuring that stable isotopes and radioisotopes are available for essential medical, industrial, and research efforts.

SUPPORTING PROGRAMS AND ACTIVITIES

DOE supports R&D programs—both domestic and international—that advance the development of civilian nuclear power. While DOE laboratories and other DOE facilities working on nuclear power have always supported domestic nuclear R&D, they are increasingly working through cooperative agreements to assist in the efforts of other nations. Such agreements enable the Department to benefit from the work of the DOE laboratories and facilities and from the R&D activities of the other countries.

Test Facilities

DOE's nuclear test facilities have been used to develop and verify advances in technologies related to fuel, reactors and reactor systems, and power conversion equipment for use in civilian, space, and defense nuclear power systems, fusion energy systems, and other DOE programs. They have provided critical resources to help resolve the technical and cost uncertainties associated with the development of new technology. In 1992 and 1993, the test facilities included the Experimental Breeder Reactor-II (EBR-II), the Fuel Cycle Facility, and supporting facilities at the ANL-West complex near Idaho Falls, Idaho; the Energy Technology Engineering Center, located near Los Angeles, California; and the Fast Flux Test Facility at Hanford, Washington. With the changes in the advanced reactor program, activities at ANL-West will be directed in 1994 to support R&D on the technological and economic feasibility of the actinide recycle process. Advanced reactor R&D at the Energy Technology Engineering Center will be closed out in 1994, and the decision to begin phased shutdown of the Fast Flux Test Facility was transmitted to Congress on December 15, 1993.

Experimental Breeder Reactor-II

EBR-II is a sodium-cooled fast reactor operating at 62.5 megawatts-thermal. It includes a complete electric powerplant generating approximately 20 megawatts-electric. The testing program at this reactor has been directed primarily toward confirming the performance and integrity of advanced metal fuels.

Principal activities at EBR-II during 1992 and 1993 included continued operation as an electric powerplant, testing of metal fuel under steady-state and extended operational overpower transient conditions for the Actinide Recycle Program, testing of mixed oxide fuel under steady-state and extended operational overpower transient conditions for the joint U.S.-Japanese Run Beyond Clad Breach and Operational Transient Testing Program, and testing of materials for the fusion program.

Consistent with the redirection of advanced reactor R&D to focus on actinide recycle technology, the Department is planning for the shutdown of EBR-II. Beginning in 1994, the blanket assemblies will be removed for processing in the Fuel Cycle Facility into an acceptable form for long-term storage. Current plans call for placing EBR-II and supporting facilities into an industrially and radiologically safe shutdown condition by the end of 1998.

Fuel Manufacturing Facility

The Fuel Manufacturing Facility at ANL-West fabricates fuel pins, elements, subassemblies, experiments, and other core-related components for EBR-II. During 1992 and 1993, this facility produced core components essential to the operation of the reactor and to carrying out experimental programs. The Department is planning for the shutdown of this facility, consistent with the redirection of advanced reactor R&D to focus on actinide recycle technology.

Fuel Cycle Facility

The Fuel Cycle Facility, also located at ANL-West, is a hot-cell facility most recently used to examine irradiated fuels and materials. It is being extensively modified to demonstrate the electrorefining method of reprocessing and fabricating fuels and to carry out work related to actinide recycle R&D. In 1992, these modifications continued. In early 1993, preoperational startup activities, including qualification of process equipment with depleted uranium, were initiated. The Fuel Cycle Facility is scheduled to begin operations in 1994 to process the depleted uranium blanket subassemblies and spent driver assemblies from EBR-II into a form suitable for acceptance into a future high-level repository.

Analytical Laboratory

The Analytical Laboratory is a support laboratory for ANL-West. During 1992, it was used for analysis of primary

and secondary sodium coolant samples, cover gas, irradiated fuel and cladding samples from EBR-II, and irradiated fuel from the Transient Reactor Test Facility. An upgrade of this facility to provide reliable support for the ANL-West site was initiated in 1992. Beginning in 1994, it will serve as a support facility for spent fuel and blanket processing activities conducted at the Fuel Cycle Facility.

Hot Fuels Examination Facility

The Hot Fuels Examination Facility at ANL-West is a hot-cell facility used to examine irradiated fuels and characterize materials. Examination of experimental advanced metal fuels continued at this facility during 1992 and 1993, and characterization operations for the Waste Isolation Pilot Plant began. The Department is planning for the shutdown of this facility, consistent with the redirection of advanced reactor R&D.

Transient Reactor Test Facility

ANL-West's Transient Reactor Test Facility tests the performance of metal fuels under severe-accident conditions to determine safety margins and to obtain data for developing fuel performance codes. It also conducts other tests for DOE and DOE programs. In 1992, work at this facility was devoted primarily to continuing and completing experimental activities for the New Production Reactor Program's heavy-water reactor concept and testing to establish the margins of safety for IFR fuel. The Department is planning for the shutdown of this facility, consistent with the redirection of advanced reactor R&D.

Zero Power Physics Reactor

The Zero Power Physics Reactor, also located at ANL-West, provides physics information for reactor designs. Past applications include support of design options for ALMR and space and defense power system programs. Currently, the Zero Power Physics Reactor is in nonoperational standby. Consistent with the redirection of advanced reactor R&D, the Department is planning for the shutdown of this facility.

Energy Technology Engineering Center

The Energy Technology Engineering Center, located near Los Angeles, California, focuses on developing and testing components and other hardware for advanced power systems. It has the capability to test both models and full-

size components under simulated normal and extreme powerplant operating conditions. The center's principal facility, the Sodium Components Test Installation, is used primarily to conduct performance and endurance tests on steam generators. Under a cooperative program with the Japan Atomic Power Company, tests on two double-wall tube advanced steam generators began at the Sodium Components Test Installation in 1991. The advanced steam generators, developed for use in ALMRs, offer the potential for improved reliability and efficiency. These tests were scheduled to be completed in September 1993. At the conclusion of this work, DOE will begin to close out ALMR Program activities at the Center.

Fast Flux Test Facility

The Fast Flux Test Facility, located at the Hanford site near Richland, Washington, is a sodium-cooled, fast-neutron-flux, low-pressure, high-temperature reactor operating at 400 megawatts-thermal. It has provided support for civilian nuclear energy, space and defense power, fusion energy, and other programs as a broad-based national irradiation facility for fuels and materials development. In April 1992, DOE placed this facility in hot standby pending the results of additional efforts to identify a significant long-term mission that would justify its continued operation.

In early 1993, the Department advised Congress that the reactor would be placed in cold standby beginning in February of the same year. However, subsequent deliberations between Congress and the Secretary resulted in a decision to defer cold standby, pending the conduct of an independent study to explore a multimission role for the facility. Based on the results of this study, the decision was made to begin the phased shutdown of this reactor. Congress was duly notified of this decision in December 1993.

Cooperative Programs

International cooperative programs in technical R&D are helping to establish an efficient, economic, safe, and environmentally sound nuclear power regime. Shared efforts lead to greater technical knowledge and lower R&D costs and thus are mutually beneficial to all participating countries and organizations.

U.S. Assistance to the Newly Independent States

The program being constructed by DOE to provide assistance to the Newly Independent States of the former Soviet Union consists of the following three components:

1. Implementing measures to provide immediate operational safety improvements
2. Providing key interim risk-reduction measures for RBMK and VVER 440/230 reactors
3. Establishing nuclear safety training centers

Operational safety enhancement activities build upon the U.S.-Soviet Initiative on Operational Safety for VVER 440/230 reactors begun in 1990. That initiative involved the application of lessons learned in the United States over the last 20 years in the development of symptom-based emergency operating instructions, performance-based training materials, and improved work-control processes and control room logs. The Institute for Nuclear Power Operations and key utility representatives are assisting DOE in transferring U.S. expertise and experience. Emergency operating instructions are scheduled for implementation at the Novovoronezh VVER 440 model 230 plants in early 1994.

The follow-on Lisbon Initiative includes expedited development of emergency operating instructions, performance-based emergency operating instruction training, and administrative and operational controls for VVER 440/213, VVER 1000/320, and RBMK reactors in Russia and Ukraine. Agreement has been reached on target sites for development of the emergency operating instructions: Rovno (Ukraine) and Kola (Russia) for VVER 440/213s, Balakovo (Russia) and Zaporozhye (Ukraine) for the VVER 1000/320s, and Smolensk (Russia) for the RBMKs.

Discussions on risk reduction have produced agreement on implementation of fire-safety improvements at an RBMK reactor (Smolensk) and a VVER 1000/320 reactor (Zaporozhye). Fire-safety walkdowns have been completed at two units at Smolensk and two units at Zaporozhye. Russian and Ukrainian fire-safety experts have worked with two U.S. architect-engineering firms to use the results of these walkdowns to complete fire-hazard analyses and develop appropriate recommendations for equipment and training that will improve fire protection, detection, and management. Testing of sample equipment is in progress.

In addition, the United States has initiated feasibility and conceptual design studies of other risk-reduction actions. Discussions with Russia to identify specific upgrades acceptable to all parties are nearly complete. These upgrades will further reduce the risk inherent in operation of the VVER 440/230 and RBMK reactors but will not prolong their lifetimes. (Ukraine has no 230s, and its only RBMKs, at Chernobyl, are scheduled to be closed by the end of 1993.) The Department will assist in establishing training centers at the Balakovo Nuclear Power Station in Russia and the Khmelnistky Nuclear Power Station in Ukraine. A full-scope training simulator will be provided to Ukraine.

Bilateral Initiatives in Central and Eastern Europe

DOE began its nuclear safety assistance program for Eastern Europe in 1991 as part of the Agency for International Development's Regional Energy Efficiency Project to promote efficient and environmentally sound nuclear and nonnuclear energy use in Central and Eastern European countries.

DOE, in coordination with the International Atomic Energy Agency, funded a review of the site and seismic safety aspects of the Kozloduy nuclear powerplant in Bulgaria and recommended improvements. Also at Kozloduy, DOE funded the purchase of a plant transient analyzer developed by Brookhaven National Laboratory. This device provides Bulgaria with the ability to model and analyze operational transients for VVER 440/230 nuclear reactors. Other projects for Bulgaria include a piping system safety assessment and the upcoming purchase of firetrucks and diesel generators.

In addition, Slovakia will receive a personal-computer-based real-time plant analyzer, including hardware and software, to upgrade the training of its nuclear reactor operators, and Lithuania will receive a software package (RELAP 5) to use in modeling accident scenarios at the Ignalina RBMKs. An RBMK plant analyzer will also go to Lithuania, as will a new communications network to upgrade Lithuania's ability to respond to operational emergencies. These three countries, as well as Hungary and the Czech Republic, will also participate in the operational safety program contracted to the Institute for Nuclear Power Operations (described in the previous section).

Other International Programs

DOE is pursuing cooperative technology exchange activities with other nations in the areas of reactor design, shield-

ing, fuel cycles, actinide burning, and testing of liquid-metal reactors and high-temperature gas-cooled reactors. Agreements with France, Germany, Japan, Switzerland, and the United Kingdom mostly involve cost sharing, either by exchanging services and technology or by foreign funding of U.S. efforts. Because of the past and continuing success of existing international agreements, which mutually benefit all of the participating countries, DOE intends to expand these cooperative R&D efforts.

SPACE AND DEFENSE POWER SYSTEMS

DOE seeks to meet the special energy requirements of the National Aeronautics and Space Administration (NASA) and the Department of Defense (DOD) through the design, development, production, and testing of radioisotope and nuclear reactor power systems. In this supporting role, DOE enters into both bilateral and trilateral technical and funding arrangements with these agencies.

Radioisotope thermoelectric generators (RTGs) are used to supply electricity requirements of less than 1 kilowatt. They operate by converting the heat of a decaying radioisotope into electricity by use of a static (thermoelectric) conversion system. Space reactor power systems develop their power through the controlled fission of uranium-235, using either thermoelectric or thermionic conversion. Development efforts have been conducted on both reactor concepts to support space nuclear power requirements ranging from 5 up to several hundred kilowatts. Thermoelectric power conversion, used in the SP-100 space reactor power system and in RTGs, uses the heating of the junction of dissimilar materials to produce an electrical current. Thermionic power conversion, used in space reactor power systems being developed in support of DOD, is achieved by heating an emitter surface to drive charged particles across a gap to a collector, thereby generating an electrical current.

DOE provided the general-purpose heat-source RTGs and lightweight radioisotope heater units now in use on the *Galileo* spacecraft's (Figure 4-2) mission to Jupiter, launched on October 19, 1989, and the *Ulysses* spacecraft's mission to the Sun, launched on October 6, 1990. In December 1992, *Galileo* successfully completed its final Earth-gravity-assist maneuver before proceeding on the final leg of its flight to Jupiter. Cooperative efforts such as these will continue under a 1991 memorandum of understanding with NASA concerning the use of radioisotope power systems for future spacecraft.

4-2. NASA Galileo spacecraft, powered by radioisotope thermoelectric generators, was launched in 1989 to Jupiter.

To provide an additional source of fuel for future RTGs, DOE obtained Presidential approval for, and in 1992 signed a contract with, Russia for the purchase of plutonium-238. Fabrication of RTGs for the NASA Cassini mission also continued in 1992. The scheduled launch date for this mission is October 1997.

In the space reactor area, DOE made significant technical progress on the SP-100 space reactor power system in 1992 and 1993, such that a demonstration of the components needed to fabricate a flight-ready power system could have taken place within approximately one year if the program had continued. However, program termination was initiated in late 1993.

The Department also awarded two competing industrial contracts to develop thermionic space nuclear reactor power system designs for military missions and to demonstrate critical technologies and components supporting those designs. Performance testing of thermionic fuel elements also progressed and, during 1993, the Department conducted an independent safety study of the Russian TOPAZ-II space reactor power system.

DOE continues to provide technical support to the U.S. delegation to the United Nations Committee on the Peaceful Uses of Outer Space, which in 1992 completed and presented to the U.N. General Assembly for adoption a set of principles that provide guidelines and criteria for the safe use of nuclear power sources in space.

SP-100 Space Reactor Power System

The goal of the SP-100 space reactor program, which began in 1983 as a cooperative project sponsored by DOE, DOD, and NASA, was to develop a reactor power system to provide electric power in space in the range of tens to hundreds of kilowatts. In recent years, much of NASA's planning for future manned and unmanned missions incorporated the use of nuclear power. Nuclear electric propulsion was identified as essential for many science missions to the outer planets and the asteroid belt, and almost all NASA planning for manned missions to Mars or extended missions to the Moon called for the use of nuclear power. However, NASA has not made a commitment to a mission that would use a reactor power system and has deferred many of the potential missions. In addition, as a result of changing DOD mission priorities, the Strategic Defense Initiative Organization (SDIO), now called the Ballistic Missile Defense Organization, withdrew from the SP-100 program in 1992 to concentrate on testing a Russian TOPAZ-II thermionic reactor system. Consequently, efforts on the SP-100 program and on thermionic fuel elements are to be phased out during 1994.

Technical work on the SP-100 program in 1992 and 1993 focused on component fabrication and testing and a demonstration of the ability to fabricate a flight-ready power system. The technology required to fabricate prototypes of all key components could be demonstrated within a year. Fabrication and performance testing of an early generation of the thermoelectric cells for the power conversion assembly and the liquid-metal pump, both key elements of and challenges for the program, took place in 1993. Demonstration models of the pump and converter were also assembled in 1993. This progress follows the detailed system design review and hydraulic flow testing of the reactor design completed earlier. The reactor fuel for a flight system has been fabricated and qualified, and techniques for fabricating the reactor from refractory niobium alloys also have been demonstrated.

In early 1993, several commercial firms expressed interest in using an SP-100 power system for high-power direct-communications satellites or to provide power for research platforms in space. This interest stems from the fact that the first demonstration of a reactor power system at a useful power level and with a useful lifetime could change the economics of space operations, making commercialization of space for communications and resource development for space enterprises, as well as NASA and DOD missions, less costly or even profitable. Industry

submitted a proposal to DOE to explore these applications, and the Department is nearing completion of an evaluation of that proposal.

Thermionic Space Nuclear Power System

In 1991, DOE, the Air Force, and SDIO initiated the Thermionic Space Nuclear Power System Design and Technology Demonstration Program to provide baseline thermionic space nuclear power system designs (at 40 kilowatts-electric, scalable over a range of 5 to 40 kilowatts-electric) and advance the system technology to a point where a flight demonstration decision could be supported at the end of 1995. In 1992, DOE awarded two competing contracts to pursue the design and development of two different thermionic concepts. Each contractor has a significant subcontract with a Russian institute to gain from Russia's expertise and technology in this area. The objective is to develop each design so that a decision to proceed can be considered at the end of 1994. At that time, the Government may select a single concept for further development and demonstration, with the goal of completing a preliminary design review by the end of 1995. Funding limitations in 1993 have caused the program decision milestones to be deferred by at least 1 year. DOE is managing this activity, with funding provided by DOD, consistent with DOE's responsibility to develop nuclear technologies and systems responsive to user requirements.

Thermionic Fuel Element Verification Program

DOE and SDIO established the Thermionic Fuel Element (TFE) Verification Program in 1986 to demonstrate the technology readiness of a TFE suitable for use as the basic element in a fast spectrum thermionic reactor operating at 0.5 to 5.0 megawatts-electric. In 1992, SDIO withdrew from this program because of funding reductions. DOE then restructured the program to support the Thermionic Space Nuclear Power System Design and Technology Demonstration Program contracts, which are based on thermal-spectrum reactor designs with lower power levels and shorter lifetime requirements. In April 1993, irradiation testing of a six-cell TFE began in the TRIGA reactor at General Atomics Company in San Diego, California. These tests were to demonstrate the performance and lifetime of a near-prototypic TFE. In late 1993, DOE began termination of this program.

TOPAZ Safety Study

Anticipating a DOD request to fuel and launch a U.S.-modified Russian TOPAZ-II thermionic space reactor in the United States, DOE utilized nuclear safety expert consultants to conduct an independent safety study of that power system. The results of this study will provide the basis for the DOE response to the anticipated DOD request for authorization to fuel a modified TOPAZ-II reactor, either for ground testing or space flight.

Advanced Radioisotope Power Systems

The goals of the Advanced Radioisotope Power Systems Program are, first, to provide the technology and industrial base to meet civilian and military requirements for radioisotope power systems in present and future space and terrestrial applications and, second, to develop and build flight-qualified systems to support these applications.

Radioisotope Thermoelectric Generators for Space Systems

DOE activities in support of the NASA Cassini mission to Saturn (Figure 4-3), which will be launched in October 1997, are continuing. The Department will supply three new RTGs for this mission and will requalify as a spare

4-3. NASA Cassini spacecraft, powered by radioisotope thermoelectric generators, is scheduled to be launched in 1997 to Saturn.

unit an existing RTG that served as a spare for the *Galileo* and *Ulysses* missions. DOE will also supply 157 radioisotope heater units for the spacecraft. These units allow electronic packages to survive long periods of inactivity and the cold temperatures of outer space.

The Cassini mission is designed to explore the Saturnian system with a Saturn orbiter and an entry probe that will investigate the atmosphere of Titan, one of Saturn's moons. DOE has initiated support activities to provide the necessary RTGs and radioisotope heater units. After extensive safety reviews and oversight by independent organizations, facilities at Savannah River, South Carolina, were restarted in January 1993 and are processing the plutonium-238 in inventory for the Cassini mission. This material will be transported to Los Alamos National Laboratory, where flight-quality fuel pellets will be produced and encapsulated. In addition, the preliminary safety analysis report for the Cassini mission is being prepared, fabrication of the electrical converters has begun, manufacture of the thermoelectric devices has been qualified, and production of the flight units has begun. Final assembly and testing of the flight RTGs will be conducted at the Mound Plant in Ohio.

Until recently, plutonium-238 for RTGs was produced in the United States as an adjunct to DOE's production of weapon materials. However, because of the changing world situation, weapon production has been curtailed, and the facilities to produce plutonium-238 no longer will be operated. NASA has identified plans for additional missions beyond Cassini, which will require more plutonium-238 than is available in the U.S. inventory. Thus, in March 1992, DOE was authorized to enter into negotiations with Russia to purchase up to 40 kilograms (88 pounds) of plutonium-238. These negotiations led to the signing of a contract in December 1992 to purchase an initial 5 kilograms (11 pounds), with options to buy additional quantities. Final approval to ship the first batch was in process at the end of 1993.

In 1992, DOE conducted a study of the facilities that it will need to support future NASA missions. The study concluded that the facilities at Los Alamos and the Mound Plant are sufficient to satisfy future RTG encapsulation, assembly, and testing requirements (most of the plutonium-238 purchased from Russia does not require further processing). The need for more efficient energy conversion systems for future missions is under review. Such systems, if budget limitations permit their development, would lead to lighter power supplies and a reduction in plutonium-238 requirements.

Radioisotope Thermoelectric Generators for Special Terrestrial Nuclear Power Systems

In 1992, DOE continued to develop thermoelectric and heat-source technology to meet DOD interest in using low- and medium-power RTGs for terrestrial applications on various national security missions. The potential applications in terrestrial environments place greater demands upon RTGs for safe operation, high reliability, and long lifetimes, and somewhat lesser demands for high specific power, than the demands placed on RTGs designed for space applications. Several compact thermoelectric converter units developed by DOE can be used to meet these low power requirements. Continued testing has verified the high reliability and operational performance of the units. Future efforts will place increased emphasis on improved design, testing, efficiency, reliability, and safety.

NUCLEAR ENERGY SELF-ASSESSMENT

In 1992, the Office of Nuclear Energy Self-Assessment evaluated the environmental, safety, and health aspects of many of the Office of Nuclear Energy's reactor and nonreactor nuclear facilities. Management organizations at Headquarters and quality assurance programs at the Idaho National Engineering Laboratory and Oak Ridge National Laboratory were also evaluated.

The office promoted the self-assessment process within line organizations through frequent contact with program management and field office and contractor personnel. The office also compiled quarterly reports on the environmental and safety performance of its major facilities. By the end of 1993, the Office of Nuclear Energy's line organizations had developed sufficient self-assessment capabilities to allow the Office of Nuclear Energy Self-Assessment to be dissolved.

CHAPTER 5

CIVILIAN RADIOACTIVE WASTE MANAGEMENT

INTRODUCTION

The mission of the Civilian Radioactive Waste Management Program was explicitly established by the Nuclear Waste Policy Act of 1982 (Public Law 97-425) and significantly streamlined and focused by amendments to that act in 1987. The Office of Civilian Radioactive Waste Management is responsible for disposal of the Nation's spent nuclear fuel from commercial nuclear reactors and high-level radioactive waste from defense activities in an economically viable manner that protects public health and safety and environmental quality.

To accomplish this mission, the office is developing an integrated waste management system culminating in a geologic repository for permanent disposal deep beneath the surface of the Earth. The goals of the Civilian Radioactive Waste Management Program currently include:

1. Determining as quickly as possible whether Yucca Mountain, Nevada, selected by the Congress in 1987 as the only site currently to be evaluated, is suitable for a geologic repository
2. Resolving the issue of acceptance of spent fuel from utilities in 1998
3. Developing more effective working relationships with external parties who have an interest in the waste disposal mission.

January 1993 marked the 10th anniversary of the signing of the Nuclear Waste Policy Act. While the long-term nature of the Civilian Radioactive Waste Management

Program does not lend itself to simple, annual measures of progress, 1992 and 1993 saw significant advances toward the program's primary goals and objectives.

The overall waste management program was examined to determine the potential need for additional disposal, storage, and transportation capabilities. The program continued to investigate the candidate site at Yucca Mountain, Nevada, to determine its suitability for a geologic repository. The feasibility of a multipurpose canister system for waste storage, transportation, and disposal was examined. The program supported a unique voluntary siting effort for a temporary storage facility through the Office of the Nuclear Waste Negotiator. Components of a transportation system continued to be developed. Two-way communication was strengthened with stakeholders through public involvement, education, and public information.

An overview of the significant accomplishments of the Office of Civilian Radioactive Waste Management follows.

PROGRAM REVIEW

In April 1993, the Secretary provided an initial assessment of the Office of Civilian Radioactive Waste Management, with emphasis on site characterization at Yucca Mountain. The Secretary stated, "The program needs to refocus its efforts and improve in two broad areas: increased emphasis on the highest quality scientific work and the more effective inclusion of external parties in program development and implementation."

The Secretary identified specific areas for reconsideration or external consultation. These areas include an approach to the 1998 waste acceptance requirement, including possible utility compensation alternatives; a full range of options for near-term storage of spent fuel pending ultimate disposal; and alternative repository licensing strategies.

The Secretary's guidance also identified new activities and policies. To enhance the program's scientific credibility, the Secretary committed to creating a position for a Chief Scientist to oversee scientific investigations at Yucca Mountain. The Chief Scientist would be responsible for ensuring that all work conducted at Yucca Mountain is of the highest scientific quality and would focus on issues critical to determining the suitability of the site. Input from stakeholders on a detailed position description is currently being solicited.

To ensure that adequate and consistent resources are available to meet program needs, the Secretary has proposed to Congress a funding approach that will provide an increasing annual funding profile over the next several years. Under this proposal, funding would continue to be requested from the Nuclear Waste Fund and the Defense Nuclear Waste Disposal appropriations. Additional funding would be provided by making available to the program an additional portion of each year's utility fee receipts. Currently, utility fee receipts not appropriated for the program are retained in the Nuclear Waste Fund but are not available for obligation. Under the Secretary's proposal, each fiscal year, one-half of the utility fee receipts in excess of the President's discretionary budget for the program and one-half of the utility fee receipts remaining from previous fiscal years, beginning with fiscal year 1995, would be available for the waste management program.

A key objective in the Secretary's guidance was to establish a process that will ensure serious and systematic involvement of the program's stakeholders in shaping decisions. A first step toward developing such a process was the Workshop on the Consultative Process, held in Las Vegas, Nevada, in August 1993. Public meetings on specific program activities, such as the report on the adequacy of current plans to manage waste from new nuclear powerplants (required by section 803 of the Energy Policy Act of 1992), multipurpose canisters, transportation issues, and system architecture, were held to involve stakeholders further.

The Secretary's review of the Civilian Radioactive Waste Management Program continues. This review includes meetings with interested parties—state, local, and Indian

tribal government representatives, public utility commissioners, representatives of the utility industry, and environmental and public interest groups—and an independent study of significant published comments that have been made about the program over the past several years, including the March 1993 special report of the Nuclear Waste Technical Review Board, created to provide an independent expert review of the scientific and technical aspects of the program, and the May 1993 General Accounting Office report on the Yucca Mountain project. In June 1993, the Secretary proposed an independent financial and management review of the Yucca Mountain Site Characterization Project. A two-person panel, one member selected by the State of Nevada and the other by the Secretary of Energy, will ensure the independence of the review and enhance the credibility of the results.

With input from these sources, as well as from concurrent efforts such as public review of the Alternative Program Strategy Task Force's report and of the Secretary of Energy Advisory Board report on public trust and confidence, the Secretary will weigh recommendations and make final decisions concerning the program.

GEOLOGIC DISPOSAL

In 1985, the Organization for Economic Cooperation and Development's Nuclear Energy Agency, headquartered in Paris, France, published a major opinion stating that disposal in deep geologic repositories is the preferred method of permanently isolating spent nuclear fuel and high-level radioactive waste. This conclusion has been established worldwide; Belgium, Canada, Finland, France, Germany, Japan, Spain, Sweden, Switzerland, and the United Kingdom are all pursuing geologic repository strategies. The Nuclear Waste Policy Act, as amended, directs DOE to evaluate the suitability of Yucca Mountain, Nevada, as the first geologic repository in the United States and provides a timeframe for assessing the need for and making recommendations on a second repository.

One of the program's two major issues is ensuring efficient progress toward determination of the suitability of the Yucca Mountain site for a permanent repository and, if it is suitable, proceeding with licensing and construction of a repository. By suitable, scientists mean that the rock will keep high-level radioactive waste sufficiently isolated deep below the mountain's surface for thousands of years so that radioactive material will not cause harm to people or the environment.

Site Characterization

Many scientific and technical issues must be resolved to determine if Yucca Mountain is suitable for a geologic repository. These issues include the following:

1. The effect of the site's hydrology and chemistry on the waste package and on the waste itself
2. The time required for groundwater to flow from the potential repository to the accessible environment
3. The effects volcanic activity might have on a repository at Yucca Mountain
4. The effects an earthquake might have on a repository and the underlying water table
5. The effect of the thermal properties of the waste on the performance of the engineered and natural barriers

One of the program's strategic objectives is to determine, as soon as possible, whether the Yucca Mountain candidate site is suitable for development as a potential repository. In February 1992, the Office of Civilian Radioactive Waste Management released an early site suitability evaluation report for public comment. The evaluation was conducted, first, to determine if any disqualifying factors had been found that precluded further site characterization and, second, to help the program focus its near-term investigations on those aspects of Yucca Mountain that might still disqualify it as a repository site. The report concluded that evidence currently available shows no technical reason to halt studies of the Yucca Mountain site.

In 1992 and 1993, the Yucca Mountain Site Characterization Project Office continued to conduct extensive surface-based geologic investigations. In March 1993, the first borehole of the unsaturated zone drilling program was completed at approximately 514 meters (1,686 feet), about 20 meters (65 feet) into the water table (Figure 5-1). A second borehole was initiated in April 1993 and had reached a depth of 439 meters (1,440 feet) by the end of 1993. Data from tests performed in these boreholes will assist in determining the distribution and movement of water at the site, a critical factor affecting the ability of the site to minimize the migration of radionuclides—radioactive atoms—from the stored waste to the accessible environment.

Other boreholes were drilled into and surrounding Yucca Mountain to obtain information on geological structure, faults, rock characteristics, depth to the water table, water

5-1. LM-300 drill rig at the UZ-16 drillhole at the Yucca Mountain site.

quality, infiltration of water into the rock body, and water movement in soil and rock.

Trenches and test pits were excavated to expose subsurface layers of soil and rock to allow evaluation of possible geologic faults, the history of past climates, and volcanic history. In 1993, the Yucca Mountain project completed the fault-trenching program in Midway Valley, a site which may be used for repository surface facilities. The geologic deposits exposed in these trenches are being examined for evidence of how frequently and in what directions displacement has occurred along these faults. No active faults have been found to date that could cause ground displacement in the vicinity of the planned surface facilities. An earthquake that occurred near the site in June 1992 provided project scientists with much useful, firsthand data on how future seismic activity might affect the potential repository site.

Ongoing studies are focused on the analysis of naturally occurring minerals in the volcanic rocks and fractures to assess the history of water movement through the mountain in the last 8 million years, and the potential role that these minerals, called zeolites, may play in retarding the migration of radionuclides from a repository.

Surface-based testing alone will not provide the critical data needed to determine the suitability of the site. One of the most significant of the program's accomplishments was the November 1992 groundbreaking for the Exploratory Studies Facility, an underground laboratory consisting of up to 22 kilometers (14 miles) of U-shaped tunnels on two levels cut through Yucca Mountain (Figure 5-2). The Exploratory Studies Facility will allow scientists to conduct detailed studies that will help them understand the complex geologic, geochemical, hydrologic and seismic conditions at the planned depth of the repository.

In December 1991, the Yucca Mountain Site Characterization Project Office received Under Secretary and Energy System Acquisition Advisory Board approval to develop final designs for the Exploratory Studies Facility. In November 1992, the Advisory Board approved site preparation, and work on the 12-acre north portal entrance pad began. In April 1993, workers began excavations for the north ramp starter tunnel, or launch chamber, for a tunnel-boring machine. The starter tunnel, approximately 60 meters (200 feet) long, was completed in September 1993. Even before the rest of the Exploratory Studies Fa-

cility is completed, the starter tunnel will provide scientists with important information, such as stress changes in the surrounding rock during excavation. Geologists have begun mapping geologic features, including potential faults, while hydrologists are evaluating the possible presence of water. Excavation of the first test alcove was completed in December 1993.

A contract for a 7.6-meter (25-foot) diameter tunnel boring machine was awarded in 1993. The machine was delivered in April 1994, allowing its assembly to be completed and tunnel boring to begin by September 1994.

Environmental Protection

The Nuclear Waste Policy Act of 1982, as amended, requires DOE to conduct site characterization activities at the Yucca Mountain site with as little negative impact on the physical, human, plant, and animal environment as practicable. In 1992, the Office of Civilian Radioactive Waste Management completed the report *Floodplain*

5-2. Preliminary design of the Exploratory Studies Facility.

Assessment and Statement of Findings, which concludes that activities involving construction of the proposed Exploratory Studies Facility at Yucca Mountain would have no significant effect on floodplains in the area, nor would there be any cumulative impacts from site characterization activities. Early in 1993, an environmental audit program was established for the Yucca Mountain Site Characterization Project to provide assurance that environmental regulatory requirements are properly satisfied. Three formal audits were conducted in 1993. The Yucca Mountain project also issued a revised environmental protection implementation plan in 1993.

The Yucca Mountain Site Characterization Project continued a number of field programs established to ensure minimal harm to the environment. Many of these field programs are conducted by permit and remain in strict compliance with local, state, and Federal regulations. These programs include air quality and meteorological monitoring, radiological monitoring, a cultural resources program, terrestrial ecosystem studies, reclamation studies, and water resource monitoring.

Engineered Barriers

Engineered barriers are the manmade components of a disposal system, including the waste package itself. The waste package for the geologic repository is being designed to provide substantially complete containment of the waste for at least several hundred years and possibly thousands of years.

Advanced conceptual design activities for the waste package and the potential repository began in October 1992. Seven specific waste package concepts that combine different characteristics—for example, thin-walled and thick-walled, self-shielded and non-self-shielded, and small and large packages—have been identified for evaluation. In September 1993, the Office of Civilian Radioactive Waste Management sponsored the Waste Package Development Workshop. Its objective was to provide a forum to discuss ideas relative to all aspects of container development, such as containment barrier degradation, selection of materials, and performance assessment.

Studies were completed that identified a range of thermal-loading alternatives that would be suitable for a repository at Yucca Mountain. Thermal loading refers to the heat output of high-level waste emplaced in a repository. Scientific studies are underway to evaluate thermal effects on the natural and engineered barriers of a potential repository.

ADVANCED TECHNOLOGIES FOR NEAR-TERM STORAGE

Multipurpose Canister

In 1993, the Office of Civilian Radioactive Waste Management completed a feasibility study and conceptual design report on a multipurpose canister system for potential use in storing, transporting, and disposing of spent nuclear fuel, evaluating how that technology can be incorporated into the waste management system. The multipurpose canister would be loaded with multiple assemblies of spent nuclear fuel and sealed at a reactor site, stored in a dry storage cask or facility at the reactor site if necessary, and then transferred intact to a transportation cask for delivery to a monitored retrievable storage facility or to the repository.

The multipurpose canister would reduce the need for routine handling of spent nuclear fuel at the monitored retrievable storage facility and repository, which would simplify operations and reduce the amount of low-level waste generated. In addition, the multipurpose canister would be suitable for storing spent nuclear fuel at powerplants.

As part of the evaluation process, the Office of Civilian Radioactive Waste Management's Office of Storage and Transportation held two public workshops for utilities, stakeholders, and other interested parties in July and November 1993 to increase their involvement in and understanding of the multipurpose canister concept. These workshops were designed to ensure that all issues and alternatives related to implementation of the concept were identified prior to a decision regarding use of the technology in the waste management system.

The evaluation concluded that the multipurpose canister concept offers significant advantages for a more integrated approach to spent fuel management at both utility storage sites and within the Federal waste management system. In February 1994, the Secretary of Energy directed the office to proceed with the next phase of the development program.

Monitored Retrievable Storage Facility

The Nuclear Waste Policy Act of 1982, as amended, authorizes the Office of Civilian Radioactive Waste Man-

agement to site, construct, and operate a monitored retrievable storage facility, an aboveground engineered facility at which radioactive waste would be stored temporarily before being transported to the repository.

Facility Design

In November 1992, the Office of Civilian Radioactive Waste Management completed a conceptual design report on the monitored retrievable storage facility. The design was developed by examining the requirements for safety, compliance with environmental regulations, and licensing. Six storage concepts were considered, and a complete conceptual design, including feasibility, costs, and construction time, was developed for each. The report concluded that a storage facility can be designed and operated in compliance with all applicable Federal regulations. Once a site for a storage facility is identified, site-specific designs will be developed. The conceptual design report was updated in September 1993 to reflect a facility based on the multipurpose canister concept.

Facility Siting

During the past 2 years, the Office of Civilian Radioactive Waste Management has supported a unique voluntary approach to monitored retrievable storage facility siting. The Nuclear Waste Negotiator, appointed by the President and confirmed by the Senate in 1990, took the lead in seeking a voluntary host—a willing state or Indian tribe with a technically qualified site—with whom to negotiate a proposed agreement on reasonable terms.

In conjunction with this voluntary siting process, DOE made phased financial assistance grants available to help states, Indian tribes, and local governments assess the feasibility of hosting a storage facility within their own jurisdictions. The grants were designed to help the recipients gather and disseminate to their communities information about nuclear waste issues in general and about technical, health and safety, and economic issues directly related to construction and operation of a temporary storage facility.

Initial (Phase I) grants of up to \$100,000 were awarded for preliminary feasibility studies of siting a monitored retrievable storage facility within the applicants' jurisdictions. Subsequent (Phase IIA) grants were intended to support more detailed examinations and further public information activities. On October 18, 1991, DOE awarded the first Phase I grant to the Mescalero Apache tribe of New Mexico. Of the 21 eventual applicants, three local

governments and nine Indian tribes were awarded initial study grants. By September 30, 1993, nine Phase IIA grant applications had been received and four Phase IIA grants for \$200,000 each had been awarded.

The third step in the voluntary siting process requires applicants to state their intent to formally negotiate hosting a monitored retrievable storage facility and to propose specific sites. If the Nuclear Waste Negotiator accepted the request for discussion, \$2.8 million Phase IIB grants would have been made available to support environmental assessments and preparations for negotiations on a siting agreement. By the end of 1993, the Mescalero Apache Tribe and the Skull Valley Band of Goshutes in Utah both had applied for Phase IIB grants. Preliminary evaluations of the technical suitability of each proposed site were carried out at the request of the Office of the Nuclear Waste Negotiator. However, the 1994 Energy and Water Development Appropriations Act precluded the award of Phase IIB grants.

Transportation

Shipping casks are the main protection against any potential radiation exposure for both workers and the public while wastes are being transported. Casks for spent fuel are certified by the Nuclear Regulatory Commission and are designed, built, and maintained according to high standards to ensure that the casks will contain their contents and provide radiation shielding, even in severe accidents.

In anticipation of shipments to either a monitored retrievable storage facility or a repository, the Office of Civilian Radioactive Waste Management is continuing its cask system development program. The first goal of this program is to develop a high-capacity cask that will hold greater quantities of spent fuel than those casks currently available and thus reduce the number of shipments. One particular cask concept, the General Atomics legal-weight truck cask, has proceeded this year toward final design and certification.

Emergency situations involving transportation of radioactive waste are a major concern of state, tribal, and local governments. Section 180(c) of the Nuclear Waste Policy Act of 1982, as amended, requires DOE to provide technical assistance and funds to states to train public safety officials in safe transportation and emergency response procedures if spent nuclear fuel or high-level radioactive waste is to be transported through their jurisdictions.

In November 1992, the Office of Civilian Radioactive Waste Management issued a report outlining its strategy for providing training assistance to state, local, and tribal governments. Under the program proposed in this report, DOE will begin to provide assistance to jurisdictions along routes leading to a monitored retrievable storage facility 3 to 5 years prior to the start of waste shipments and will provide similar assistance along the routes leading to a permanent disposal facility.

The Civilian Radioactive Waste Management Program continues to work with numerous external organizations to study and resolve issues related to transporting radioactive waste. In January 1992, the Office of Civilian Radioactive Waste Management signed a Memorandum of Agreement with the DOE's Office of Environmental Restoration and Waste Management, establishing effective coordination within the Department for emergency preparedness planning. One of the key provisions of this agreement was the development of the DOE Transportation External Coordination Working Group, whose members include representatives from state, local, and tribal governments as well as DOE.

EXTERNAL RELATIONS

Recognizing that nuclear waste management is a matter of justifiable public interest and concern, the architects of the Nuclear Waste Policy Act and its amendments crafted legislation giving an explicit role to certain parties, specifying when and how information is to be made available to the public for comment and review. Building on this blueprint, the Office of Civilian Radioactive Waste Management has established an ongoing effort to communicate with interested groups and individuals at every opportunity.

Working With Affected Governments

Federal law defines certain units of government as "affected" because of their jurisdiction over the site of a geologic repository or a monitored retrievable storage facility. The act provides that, at the discretion of the Secretary, contiguous units of local government may also be designated as "affected." Currently, Nye County, Nevada, in which the Yucca Mountain site is located, and nine con-

tiguous counties in Nevada and California are so designated. These counties are eligible for extensive participation in the program, oversight of the project during site characterization, and certain forms of financial assistance.

The Office of Civilian Radioactive Waste Management has continued its efforts to strengthen communication between its programs and affected governments. During the past 2 years, the office formalized a protocol for procedures that will enable Nye County to have onsite representation during Yucca Mountain site characterization activities and drafted a protocol for conducting cooperative drilling initiatives at the Yucca Mountain site. In 1993, bimonthly meetings between the Yucca Mountain project and affected units of government were initiated.

Financial assistance in the form of direct payments is provided to the State of Nevada and the affected counties to enable these jurisdictions to monitor site characterization activities, to inform their residents of program developments, and to develop requests for impact assistance. In addition to direct payments to the affected governments, DOE has proceeded to make payments equal to taxes as directed by the Nuclear Waste Policy Act of 1992. These payments equal the amount of taxes that would be assessed if a private organization were conducting site characterization activities. Partial payments were made in 1992 and 1993 to Nye County, Nevada, and in 1992 to Benton County, Washington, for previous site characterization activities. In November 1993, DOE additionally made payments to the State of Nevada and four other affected governments: Clark, Esmeralda, and Lincoln Counties in Nevada and Inyo County, California.

Involving Indian Tribes

Indian tribes have a unique legal and political relationship with the Federal Government, one that is defined by the Constitution, treaties, statutes, and court decisions. This relationship obligates DOE to protect and preserve tribal lands and resources and to work directly with Indian tribes affected by the Civilian Radioactive Waste Management Program on matters of concern to them.

The Office of Civilian Radioactive Waste Management continues to interact regularly with the Indian tribes and tribal groups that have traditional cultural and spiritual ties to Yucca Mountain. In 1993, the office renewed the cooperative agreement with the National Congress of American Indians, the oldest and largest American Indian advocacy organization in the country. This organization

advises DOE on tribal interests across a range of program areas, including transportation and temporary storage; monitors legislation and regulation; and updates tribes on program activities. In March 1993, more than 100 American Indians attended a meeting in Las Vegas, Nevada, to discuss their concerns about radioactive waste.

In November 1991, the Secretary announced DOE's official American Indian Policy, which outlines principles for the agency to follow in its interactions with Indian tribes recognized by the Federal Government. Building on this policy, the Office of Civilian Radioactive Waste Management is developing an Indian Policy Implementation Plan to provide formal guidelines for involving Indian tribes in the Civilian Radioactive Waste Management Program and addressing issues of concern to American Indians.

Involving the Public

The Office of Civilian Radioactive Waste Management has made a concerted effort over the past 2 years to expand and intensify its interactions with interested parties. The goal is to continue to seek new opportunities for interacting with a broader spectrum of the public and to encourage all who express an interest to join in a dialogue on the Nation's high-level radioactive waste management program.

In August 1993, the Office of Civilian Radioactive Waste Management held a day-long workshop in Las Vegas, Nevada, with invited stakeholders and interested members of the public. The purpose of the meeting was to seek stakeholder assistance in designing a broad-based consultative process that will provide these parties with meaningful opportunities to participate in decisionmaking for the long-term management of nuclear waste. Consultative meetings such as these are part of the Secretary's commitment to enhance the participation of external parties in DOE program development and implementation. More than 100 representatives from utilities, the State of Nevada, affected local governments, Indian tribes, local citizen groups, environmental groups, and the public participated. The workshop showed that there is no simple consensus among interested parties and that DOE must be available to work with different groups with different viewpoints in order to open its program to public participation.

Sharing International Expertise

During 1992 and 1993, the Office of Civilian Radioactive Waste Management continued its efforts to promote international understanding and consensus on matters related to nuclear waste. The benefits of sharing expertise include better use of funds and more timely achievement of goals. Efforts in this area included cooperative and bilateral agreements with other countries and international organizations to help identify technology, approaches, and experience that can improve or facilitate similar U.S. efforts.

One such effort, Sweden's Stripa Project, which began in 1980, culminated at a final symposium held in October 1992. A benchmark as a long-running, well managed, and highly productive multinational cooperative project, this undertaking provided the Civilian Radioactive Waste Management Program access to the Stripa mine in Sweden for onsite experiments on the capability of fractured hard rock to isolate radioactive waste. These experiments allowed program staff to develop technology for studying rock mass characteristics and broaden their understanding of fracture-flow hydrology.

In December 1992, DOE reached agreement with Sweden on developing joint experimental and analytical activities at the Hard Rock Laboratory, an underground testing facility being built in Sweden to conduct research and development in a realistic and undisturbed underground rock environment at a depth equivalent to that of a geologic repository for high-level radioactive waste.

A bilateral agreement between DOE and the Spanish Nuclear Waste Management Company (ENRESA) to allow information exchange on radioactive waste management technologies was also announced in December 1992. In addition, the United States and Canada initiated a 5-year agreement that will complement the Civilian Radioactive Waste Management Program's current site characterization activities.

A project agreement between the United States and Switzerland is aimed at developing site characterization techniques for future high-level radioactive waste repositories. The agreement covers joint research at the Grimsel Pass underground research facility and other sites and laboratories in Switzerland. The research being conducted in Switzerland is valuable for the Civilian Radioactive Waste Management Program because the instruments and techniques developed and improved from studies conducted

at the Grimsel Pass facility are being used in characterizing Yucca Mountain. In addition, models that will be used at Yucca Mountain have been developed and tested using data from the Swiss program.

PUBLIC INFORMATION AND EDUCATION

Public Information Initiatives

A wide range of external audiences—from members of the general public, educators, and students to journalists, legislators, and utility representatives—continue to express a keen interest in learning about and staying informed as to the Civilian Radioactive Waste Management Program's progress. Building on past efforts, the Office of Civilian Radioactive Waste Management strengthened its public awareness activities during 1992 and 1993 to enable more people to obtain timely program information.

Since it opened in September 1991, the Civilian Radioactive Waste Information Center has successfully filled a need for information, receiving more than 20,000 public inquiries and distributing approximately 750,000 publications during fiscal years 1992 and 1993. Anyone with questions about spent nuclear fuel and high-level radioactive waste can call a toll-free number and speak directly with an information specialist, available weekdays from 9 a.m. to 7 p.m. Eastern time at 1-800-225-NWPA (6972), or in the Washington, D.C., area at 202-488-5513.

The Office of Civilian Radioactive Waste Management continued to operate INFOLINK, a publicly accessible, interactive data base that allows users to access news releases and speeches, review information products such as backgrounders and factsheets, place orders for publications, and communicate with other users. The office also continued to publish *OCRWM Bulletin*, a quarterly newsletter that provides information to subscribers about its program activities, milestones, and events, and developed several new publications and fact sheets to inform the public on the latest program developments.

The Office of Civilian Radioactive Waste Management developed and uses several exhibits for presentations at technical and nontechnical meetings and regional and national education conferences and events. In 1992, approximately 146,000 people in 29 states at 42 events saw these exhibits; in 1993, approximately 130,000 people in 25 states at 38 events took part.

Over the past 2 years, the Yucca Mountain Site Characterization Project Office has increased its public information and outreach activities in Nevada. Two sets of public project update meetings are held each year at three locations to provide the public with an overview of current developments. In April 1992, the project office opened a third public information office, in Pahrump, Nevada, which joins the offices in Las Vegas and Beatty. These offices serve as science resource centers for information about the Yucca Mountain project, providing interactive and display exhibits, science education resource materials, and educational lectures. More than 10,000 people have visited the information office (known as the Yucca Mountain Science Center) in Las Vegas since it opened in February 1990.

The Yucca Mountain Site Characterization Project Office continued to offer monthly open houses and site tours of the Yucca Mountain candidate site (Figure 5-3). Since these activities began in March 1991, they have grown into one of the most effective outreach programs on the geologic repository. In 1992, more than 100 tours were conducted for some 5,200 guests. The 1993 tour program reached even more people. Other initiatives include developing a rural outreach program for individuals, groups, and media outside the urban centers of Nevada and working with the Boy Scouts of America and Girl Scouts of America to establish merit badges on nuclear energy and on geology.

5-3. Tour of the Yucca Mountain candidate site organized by the Yucca Mountain Project Office.

Education Initiatives

In response to continuing requests by teachers, and after years of planning, development, teacher testing, and evaluations, the Office of Civilian Radioactive Waste Management's Education and Information Division produced *Science, Society, and America's Nuclear Waste*, a new resource curriculum on nuclear waste for grades eight through twelve (Figure 5-4). This resource curriculum was introduced to teachers through a nationwide teleconference workshop in July 1992. The workshop was downlinked at almost 200 locations in all 50 states. A second teleconference, in April 1993, was seen at 296 sites and broadcast by cable networks reaching more than a million households. Since its introduction, more than 412,000 curriculum documents have been requested by teachers in all 50 states and in 32 countries.

In 1992, the Education and Information Division launched the International Education Alliance in Radioactive Waste Management, an organization established to foster science literacy in radioactive waste management through international collaboration in education. The Alliance's first project is to develop an international catalog of selected educational resource materials related to radioactive waste management.

The Office of Civilian Radioactive Waste Management strives to attract new talent into scientific and technical disciplines that the waste management program will rely upon. In 1992, the office sponsored 20 graduate fellowships for students pursuing master's or doctorate degrees in fields related to radioactive waste management—nuclear engineering, health physics, environmental engineering,

and geology. The fellowship program is integral to DOE's ability to develop and interest outstanding qualified professionals in advanced careers in these fields.

REVIEW AND OVERSIGHT

The Civilian Radioactive Waste Management Program is reviewed formally and informally for its technical expertise, scientific development, and compliance with laws and regulations, and for its reaction to public scrutiny.

Nuclear Waste Technical Review Board

The Nuclear Waste Technical Review Board is an independent group created by Congress and appointed by the President to provide independent expert review of the scientific and technical aspects of the Civilian Radioactive Waste Management Program. The board holds numerous public meetings throughout the year with representatives of the Office of Civilian Radioactive Waste Management and its contractors, other Federal agencies, the national laboratories, the State of Nevada, and interested organizations. It not only provides valuable expertise that strengthens the program technically, but also serves as a forum in which affected governments and interested parties can observe and contribute to technical deliberations.

At least twice each year, the Nuclear Waste Technical Review Board reports to Congress and the Secretary, making specific recommendations. The Office of Civilian Radioactive Waste Management formally responds to the board's recommendations; its responses are then released to the public in the board's next report. The board's recommendations have led to significant changes in the Civilian Radioactive Waste Management Program, such as using inclined ramps rather than vertical shafts in the Exploratory Studies Facility.

The National Academy of Sciences

Peer reviews of the Civilian Radioactive Waste Management Program's findings and analyses by persons with technical expertise in the field who are not directly involved with the Office of Civilian Radioactive Waste Management have many benefits. The use of independent

5-4. Education and Information Division resource curriculum on nuclear waste for grades 8 through 12.

reviewers bolsters confidence in technical soundness and strengthens program credibility.

Over the years, the Board on Radioactive Waste Management of the National Academy of Sciences has maintained an active interest in the Office of Civilian Radioactive Waste Management and has provided the benefit of its technical expertise. For example, in April 1992, a 17-member National Research Council panel of the National Academy of Sciences concluded a 2-year study, unanimously agreeing that calcite silica deposits found at the Yucca Mountain site were not caused by groundwater rising above the level of the proposed repository site in the geologically recent past, as had been asserted by a former DOE geologist (Figure 5-5).

Under the Energy Policy Act of 1992, the National Academy of Sciences is to provide the Environmental Protection Agency with "findings and recommendations on reasonable standards for protection of the public health and safety" as applied to the proposed repository site at Yucca Mountain. In May 1993, 15 members of the Academy's Committee on the Technical Bases for Yucca Mountain Standards met in Las Vegas for the first of four hearings aimed at generating public comments to be used in reevaluating existing standards intended to govern the long-term performance of a geologic repository. Among the issues the panel will address are the scientific bases for different formulations of the health standards, the scientific assumption that a repository would remain geologically isolated for 10,000 years, and the logic of the assumption that human intrusion can be prevented during that period. The committee plans to complete its study by December 1994. Site characterization at Yucca Mountain will continue during the National Academy of Sciences review and the re promulgation of environmental standards by the Environmental Protection Agency.

Issue Resolution

The Nuclear Regulatory Commission is responsible for licensing or certifying the elements of the waste management system, including transportation casks, a monitored retrievable storage facility, and the geologic repository. The Office of Civilian Radioactive Waste Management seeks input from the Commission through a process designed to resolve issues raised in prelicensing for the Yucca Mountain site characterization process. One part of this process involves Nuclear Regulatory Commission staff personnel in reviewing technical and topical reports and technical exchanges. For example, in March 1993, the

5-5. Carl Gertz describes calcite silica vein deposits in Trench 14 at the Yucca Mountain site.

Commission reviewed the Yucca Mountain Site Characterization Project Office's first topical report, "Evidence of Extreme Erosion During the Quaternary Period." A preliminary draft of a technical report on the status of volcanism studies at the Yucca Mountain site was also forwarded to the Nuclear Regulatory Commission for review and comment.

Quality Assurance

The Office of Civilian Radioactive Waste Management achieved a major accomplishment in 1992 when its quality assurance program was unconditionally accepted by the Nuclear Regulatory Commission. The Civilian Radioactive Waste Management Program now has in place a quality assurance program that meets Nuclear Regulatory Commission requirements and the nuclear industry's consensus standard for the application of quality assurance controls to nuclear facilities. A formal quality assurance program ensures the integrity of program activities while meeting one of the Commission's licensing requirements.

To ensure that the Nuclear Regulatory Commission staff is kept informed of the status of the quality assurance program, bimonthly meetings are continuing. These meetings provide a forum not only for DOE and the Nuclear Regulatory Commission and its staff, but also for utility representatives, the State of Nevada, local governments, and other affected parties who can identify and participate in the resolution of quality assurance issues.

PLANNING AND MANAGEMENT

Section 803 Report

Section 803 of the Energy Policy Act of 1992 requires the Secretary to report to Congress and the President on the adequacy of current nuclear waste management plans to manage waste from new nuclear powerplants. In its draft report, *Adequacy of Management Plans for the Future Generation of Spent Nuclear Fuel and High-Level Radioactive Waste*, the Office of Civilian Radioactive Waste Management considered the following issues:

1. The possibility of increased volumes of spent nuclear fuel or high-level radioactive waste
2. The need for additional interim storage capacity prior to final disposal and/or additional repositories for deep geologic disposal
3. Transportation of additional volumes of waste

The report concluded that current waste management programs and plans are adequate for any additional volumes and categories of nuclear waste from both commercial and defense sources.

The draft report, issued for public comment in June 1993, followed an evaluation process that invited substantive public involvement at various stages, including three public meetings. At the first of these meetings in February 1993, the draft of the annotated outline to be used in preparing the report was presented for comment from stakeholders. The comments on the annotated outline and the office's responses were then included in the draft report. After release of the draft report, two additional public meetings were held in July, in Las Vegas, Nevada, and Washington, D.C., to receive further comments. The final report is being prepared for the President and Congress.

Contract Integration

In 1991, the Office of Civilian Radioactive Waste Management awarded a 10-year management and operating contract to a team charged with consolidating program resources, strengthening program integration, and enhancing overall program progress. This contract consolidated the work previously performed under several contracts. During a transition period, the management and operating contractor developed management systems and qual-

ity assurance programs; assumed all design work for the geologic repository, the monitored retrievable storage facility, and transportation activities; and implemented procedures that enhanced regulatory compliance. In addition, the contractor is leading cost reduction and containment efforts for the Yucca Mountain project, as well as the endeavor to accelerate site evaluation efforts.

Program Management

In developing the Civilian Radioactive Waste Management Program, the Office of Civilian Radioactive Waste Management must integrate a complex set of multidisciplinary activities required by the program's combination of objectives—maximum safety, technical excellence, regulatory compliance, fiscal responsibility, meaningful public participation, and public confidence.

Over the past 2 years, the office initiated and completed a systematic review of its management requirements and implemented a number of significant improvements in its management system, including changes in program planning and control. Recently, the office began a major internal review of program activities associated with siting and developing the geologic repository. The objective of this review is to improve management and coordination of the various program activities associated with selecting a suitable site, complying with environmental policy, and developing and submitting a successful license application for the geologic repository. In addition, a business management review to examine program-wide business practices was undertaken.

The program management system for the Office of Civilian Radioactive Waste Management consists of all the baselines, plans, policies, procedures, systems, and processes that together provide the mechanism for managing the program in a cohesive, cost-efficient manner. It specifies how to plan and control all major activities in the program, including technical activities, cost and schedules, quality assurance, regulatory compliance, institutional planning, records management, and information resources management.

Information Resources Management

The Office of Civilian Radioactive Waste Management continues to develop and enhance its information resources

management program, which draws on the latest computer technology to produce, file, store, access, retrieve, and transfer an array of technical and institutional data and information. The office recently initiated the first phase of InfoSTREAMS (Information Storage, Retrieval and Access Management System), a major computerized records management system in pilot locations around the country. This system builds on existing office automation, telecommunications, records management infrastructure, and license application procedures to link users of personal computers into local- and wide-area networks and mainframe computers. Eventually, InfoSTREAMS will automate all of the office's processes involved in licensing and records management. In addition to improving the efficiency of program workflow, it will help to provide nationwide access to data systems and to capture, retain, and access program records electronically.

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CHAPTER 6

ENERGY INFORMATION

INTRODUCTION

Created by Congress in 1977 as an independent entity within the Department of Energy, the Energy Information Administration (EIA) is the principal and authoritative source of comprehensive energy data for Congress, the Federal Government, the states, and the public. With the mandate to "collect, assemble, evaluate, analyze, and disseminate data and information," EIA's mission is as follows:

1. To maintain a comprehensive data and information program pertaining to energy resources and reserves, energy production, energy demand, energy technologies, and related financial and statistical information concerning the adequacy of energy resources to meet the Nation's demands in the near and longer term future
2. To develop and maintain analytical tools and collection and processing systems; to provide analyses that are accurate, timely, and objective; and to provide information dissemination services

HIGHLIGHTS OF 1992

Actions Taken During Hurricane Andrew

EIA played a major role in providing up-to-date information during the August 23–26, 1992, devastation created

by Hurricane Andrew. EIA supplied information and support personnel to the Office of Emergency Planning and Operations during the disaster and provided the Department's Emergency Operations Center with 24-hour-a-day coverage on the current status of offshore oil and gas production and refinery, petrochemical plant, and shipping operations in the affected areas. EIA used the information gathered as input for daily briefing papers to the Secretary of Energy and for the Federal Emergency Management Agency situation reports.

EIA published twice daily the Hurricane Andrew-EIA status reports, which contained specific refinery facility, pipeline, and offshore-drilling-platform information. Using the Energy Emergency Management System, EIA gave relevant data and computer-generated maps of several energy resource types to the Office of Emergency Planning and Operations. EIA was able to quickly identify the energy facilities that were affected by the hurricane by using the Energy Emergency Management System and was then able to provide pertinent information about those facilities.

EIA monitored estimates of the damage and its impact on natural gas production, and evaluated related impacts on natural gas spot and futures prices. EIA also tracked changes in the level of underground natural gas storage and tracked natural gas, crude oil, and petroleum product prices daily.

EIA developed and prepared daily status reports on the effects of Hurricane Andrew on the electricity supply in Florida for several days following the hurricane. EIA obtained the information directly from the electric utilities. Two weeks after the hurricane, EIA provided the city of Homestead, Florida, with copies of the city's 1991 financial data submissions to EIA for its municipal utilities

because the records were lost during the hurricane. The data were used by local authorities to prepare to refit plant equipment.

After Hurricane Andrew, EIA prepared a status report of the electric power situation in Florida as of late October 1992. EIA provided information on the number of customer outages remaining, the time needed to correct outage situations, and the time needed to return plants to operation.

EIA also responded to the Federal Emergency Management Agency's urgent request for volunteers to help the Hurricane Andrew relief efforts. EIA sent some staff to the Federal Emergency Management Agency telecommunications "hotline" center in Columbus, Ohio, where they accepted local and long-distance telephone calls from victims of the hurricane and their families and friends. They referred the victims to various relief organizations, such as the American Red Cross and state employment agencies. EIA assigned other staff to the teleregistration center in Baton Rouge, Louisiana, where they helped disseminate information to the disaster victims about the availability of various types of governmental assistance. Later, EIA sent one volunteer to a Disaster Assistance Center in New Iberia, Louisiana, and another directly to the affected communities for the relief outreach program.

Increased International Outreach Activities

During 1992, U.S. citizens continued to watch with interest the events taking place in Europe, including the gradual evolution of the Newly Independent States; the civil war in Bosnia in the former Yugoslavia; the severe economic problems plaguing the reunified Germany; the imminent sundering of Czechoslovakia on January 1, 1993; the agreement, also on January 1, of the 12 nations of the European Community to allow the free flow of people, goods and services, and money in the hopes of thereby establishing a "Europe without frontiers." U.S. citizens also continued to observe the economic development in Asia and oil issues—primarily production quotas—in the Middle East. Finally, in December 1992, the United States signed the North American Free Trade Agreement with Canada and Mexico, an agreement that may significantly alter future trade among these three countries.

The United States became involved in these events—all the more so when representatives of the emerging nations began to seek its advice. When the subject was energy, these representatives applied to EIA for help, and

EIA responded. In doing so, EIA also benefited either by merely learning more in general about the energy situation in these countries or by agreeing to mutual exchanges of energy data and information.

Press Conferences on *Oil and Gas Profits and Federal Subsidies*

In mid-September 1992, the EIA Administrator held a press briefing at a meeting of the Texas Mid-Continent Oil and Gas Association on topics of great interest to the attendees: U.S. oil and gas profits during the first 6 months of 1992.

According to the Administrator, U.S. petroleum companies registered reduced earnings in all segments of the industry for the first 6 months of 1992. Every segment of the petroleum industry reported declines in net income of 20 percent or more, while net income for the 19 major integrated petroleum companies dropped by an even greater amount—37 percent. Modestly higher U.S. oil and gas prices in the second quarter of 1992 were insufficient to offset the lower prices in the first quarter, thus reducing net income for U.S. independent oil and gas producers by 24 percent from the net income reported for the first 2 quarters of 1991.

During the same period, lower product margins and reduced profits for the majors' and independents' U.S. refining and marketing operations resulted from weak economic growth, which restrained petroleum product demand. Profits of the majors' and independents' U.S. operations fell by 51 percent and 22 percent, respectively, from the first 2 quarters (or first half) of 1991. Lower margins, falling 65 percent in the first half of 1992, affected income from the majors' foreign refining operations. In spite of the modest upswing in prices in the second quarter, domestic drilling activity also continued to slide and, measured by the average rig count, reached a record low of 621 rigs in June. The Administrator noted that, for the first 6 months of 1992, income from oil field service companies dropped by 23 percent from income at the end of the first 2 quarters of 1991.

The major petroleum companies' shift toward foreign upstream investment targets and away from U.S. prospects continued in the first half of 1992. The majors' exploration and development expenditures for the United States were down 33 percent from the first half of 1991, while their foreign spending was up by 6 percent.

In contrast to the performance of the U.S. petroleum industry, the financial performance of nonenergy corpo-

rations registered double-digit increases in net income in each of the first 2 quarters of 1992. These increases followed more than 2 years of nearly unabated quarterly declines.

Later in 1992, at a press conference held at the Department, the Administrator discussed the findings of a report mandated by Congress in EIA's 1992 appropriations entitled *Federal Energy Subsidies: Direct and Indirect Interventions in Energy Markets*. The Administrator described the report as the "most comprehensive investigation undertaken since 1980 of how the Federal Government intervenes in energy markets." The report showed that energy subsidies for 1992 were between \$5 billion and \$13 billion, depending on the valuation method used. However, the value of energy subsidies is relatively small compared to annual spending of \$475 billion on energy in the U.S. economy; moreover, the Administrator noted, subsidies are vital to the creation of markets for particular fuels, such as "gasohol" (supported by tax credits) and methane produced from coal seams.

The Administrator stressed that there is neither a universally accepted definition of "subsidy" nor a valuation method applicable to every Federal program. The variation in estimates of the value of Federal energy subsidies in the report occurred because there are different methods of estimating the costs of indirect subsidies; the report, therefore, considered several alternative approaches.

Progress in Assuring Equal Employment Opportunities

In keeping with the Secretary of Energy's commitment to equal employment opportunities, EIA made considerable progress in this area. In September 1992, the EIA Administrator issued an implementation plan designed to fulfill responsibilities for the achievement of equality of opportunity for all employees in EIA. As of yearend 1992, EIA had completed all scheduled tasks listed in its implementation plan.

HIGHLIGHTS OF 1993

Energy Policy Act

EIA was actively engaged in the implementation of the Energy Policy Act of 1992 (EPACT) during 1993. EIA

provided several mandated reports to Congress. The Residential Energy Consumption Survey sample was increased, and questions regarding lighting, conservation, and demand-side management participation were added. Identification of data needs was begun for alternative fuels and alternative fuel vehicles. The first inventory of greenhouse gas emissions was published. Development of a pilot study to assess fleet composition and use was begun; the study is intended to serve as market assessment information for the Clean Cities program.

National Energy Modeling System

EIA completed the first version of the National Energy Modeling System in 1993. The new system was developed with the help of major outreach efforts to draw upon the expertise of the modeling community, industry, academia, and environmental groups to address the needs of customers both within the Department of Energy and elsewhere. Among major enhancements over previous models are expanded levels of regional detail, greater structural data in the demand models, and improved macroeconomic forecasts. The National Energy Modeling System was used to develop the projections contained in the *Annual Energy Outlook 1994*.

Clean Air Act Amendments

EIA undertook several 1993 activities associated with the Clean Air Act Amendments of 1990. Seven of the ten forms used to collect petroleum marketing data were revised to provide more relevant crude oil and propane price information. The *Petroleum Marketing Monthly* was also revised to reflect these changes. The petroleum supply data collection forms, publications, systems, and procedures were reviewed to determine revisions required by the Clean Air Act Amendments of 1990, and the revisions were begun.

Analytical Activities

EIA issued 14 analytical reports in 1993. Among these are reports dealing with the changing structure of the U.S. electric power and coal industries, historical trends in the petroleum industry, and current issues and trends in the

natural gas industry. Two reports required by EPACT on transportation rates and greenhouse gas emissions were published. Drilling techniques in the petroleum industry were addressed, as were the forecasted uses of renewable resources in the U.S. electricity supply. At the request of other federal programs, two reports were prepared dealing with spent nuclear fuel discharges from U.S. reactors and state energy price projections for the residential sector.

Comprehensive Oil and Gas Information System

For customers wishing to download large oil and gas data bases, EIA developed the Comprehensive Oil and Gas Information System (COGIS) as a reinvention laboratory project under the National Performance Review and installed it on the Department of Commerce's Economic Bulletin Board. COGIS contains virtually all of the oil and natural gas data published for the last decade by EIA in the *Petroleum Supply Monthly*, *Petroleum Marketing Monthly*, *Natural Gas Monthly*, *Weekly Petroleum Status Report*, and other reports and articles. Through the Economic Bulletin Board's Internet and dial-up services, COGIS files were downloaded more than 1,000 times by year's end, including university downloads for repackaging and retransmission that could make the total number of COGIS users many times greater.

Oil and Gas Information Resource System

For analysts wishing a highly interactive Windows or DOS environment in which to combine and manipulate oil and gas data, EIA developed the Oil and Gas Information Resource System. The Oil and Gas Information Resource System contains over 11,000 different data series from EIA petroleum and natural gas monthly publications, plus energy data series from non-EIA sources. The data base features price and volume information on an annual, monthly, and weekly basis, as well as daily and periodic international spot and future prices. Although still in testing at year's end, the Oil and Gas Information Resource System will be online within EIA in early 1994 and eventually available for departmental and external customers.

Total Quality Management

EIA began its quality journey in 1993, spurred by the Secretary's commitment to quality throughout the department and by the seminal quality program established by the Office of Oil and Gas the year before. Even in its early stages, EIA's quality journey has produced notable accomplishments. On the process side, staff communication has improved markedly, strongly facilitated by e-mail and the establishment of several informal process teams. On the products and services side, COGIS and the Oil and Gas Information Resource System, mentioned above, are good examples, as is the successful culmination of a project to release weekly petroleum data a full business day earlier than previously possible. Highlights of EIA's journey in 1993 include:

Strategic Planning

Administrator Jay E. Hakes convened a multisession, facilitated strategic planning forum among the agency's senior managers. Out of that forum, which came to be known as "Vision 2000," grew a new statement of EIA's vision, mission, and strategic goals and objectives. These results were shared widely with, and discussed extensively among, all EIA staff members. In 1994, in partnership with the National Treasury Employees Union, EIA will establish a quality council to oversee improvement activities necessary to meet the strategic goals and objectives in the years to come.

Customer Focus

One of EIA's strategic goals is to make its data and analyses relevant to the needs of its customers, in keeping with the Administration's program to set Federal customer service standards equal to the "best in business." Begun in 1993, the EIA customer focus program will include identifying current and potential customers; surveying them to determine their needs, expectations, and level of satisfaction; fashioning service standards based on this customer input; and mounting a customer awareness program within the agency so that customer focus becomes a way of life for everyone.

Performance Measurement

EIA's quality journey is also leading toward performance budgeting, as introduced in the Government Performance and Results Act of 1993, to improve the effectiveness and

efficiency of its programs by developing the information necessary to assess program performance and make resource allocation decisions. In 1993, EIA applied to be a pilot project under the Government Performance and Results Act of 1993 (the application has been approved), to become one of the early test sites for building a budget based-on performance indicators. In the early stages of the pilot project, EIA will measure customer satisfaction with its products and services, exposure of its information in the general media, electronic accessions of its data bases, and improvements in the timeliness of information release.

Symposium Issue of the *Government Information Quarterly*

The editors of *Government Information Quarterly* devoted an entire issue of this distinguished journal to EIA. The issue featured 10 articles on different facets of the agency's work, all written by EIA staff members. Subjects included survey design, data collection, data integration, data analysis, modeling and forecasting, confidentiality, and quality control. Keynoted by then Administrator Calvin A. Kent's history of the agency, which presented an interpretive framework for understanding why EIA was created and what it has accomplished, the symposium issue defines EIA contributions to the Nation's debate on energy issues.

International Activities

EIA participated in numerous international cooperative efforts in 1993. Energy data collection, analysis, and modeling issues were addressed with officials from former Centrally Planned Economy countries, including Ukraine, Poland, and Romania. Support was provided to the Nuclear Energy Agency of the Organization for Economic Cooperation and Development and the International Atomic Energy Agency for a joint report on worldwide uranium resources, production, and demand. EIA was also involved in an international effort to develop data bases and methodologies for comparative assessments of electricity generation methods to provide developing countries with information on the economic, health, and environmental impacts of each technology.

SPECIAL REPORTS, 1992

During 1992, EIA produced four analytical reports and four service reports. EIA analytical reports result from analysts' examinations of current and projected U.S. economic, regulatory, technological, and marketing trends and their impact on energy supply and demand. EIA service reports are also analyses, but EIA prepares them, as their name implies, as a service, upon specific request from other executive branch agencies or Congress. Service reports are often based on assumptions provided by the requestor.

Analytical Reports

Capacity and Service on the Interstate Natural Gas Pipeline System 1990: Regional Profiles and Analyses

This report identifies and quantifies the capability of the national natural-gas pipeline infrastructure to transport natural gas to the natural gas markets of the country. The report examines the capabilities of the pipelines that make up this network to move gas across regional and state borders and compares these levels to 1990 levels of natural gas flow to and within regional markets. In addition, EIA presents envisioned and currently approved plans to construct major new pipelines and expand existing systems, and they are assessed relative to the needs of the current and near-term marketplace. (Published: June 1992)

Energy Consumption Series: Derived Annual Estimates of Manufacturing Energy Consumption, 1974-1988

This report presents a complete series of annual estimates of purchased energy used by the manufacturing sector of the U.S. economy for the years 1974-88. These estimates interpolate over gaps in the actual data collections by deriving estimates for the missing years 1982-84 and 1986-1987. For the purposes of this report, "purchased" energy is energy brought from offsite for use at manufacturing establishments, whether the energy is purchased from an energy vendor or procured from some other source. The actual data on purchased energy come from two sources, the U.S. Department of Commerce, Bureau of the Census's *Annual Survey of Manufactures* (for 1974-81) and EIA's *Manufacturing Energy Consumption Survey* (for 1985 and 1988). EIA provides estimates of consumption

for the missing years for the manufacturing sector as a whole and at the two-digit standard industrial classification level for total energy consumption and for individual fuels consumption. The methodology for the report entails a fairly simple linear interpolation using the available energy data and production data provided by the Federal Reserve Board. (Published: August 1992)

Energy Consumption Series: Lighting in Commercial Buildings

This report provides a statistical profile of commercial lighting to permit an examination of the potential for energy conservation in lighting commercial buildings. EIA performed the analysis by using data from EIA's 1986 Nonresidential Buildings Energy Consumption Survey. Estimates of the potential savings depend heavily on assumptions regarding the types of lamps and fixtures to be replaced, the effectiveness of various lighting conservation measures, and how strong a lighting level is to be maintained. The analysis, therefore, created estimates of maximum potential savings under various scenarios. The scenarios differ, depending on what conservation features are in use and on the level and type of replacement that is made. The principal conclusion from this analysis is that energy use for commercial lighting could be reduced by as much as 80 percent by using the best currently available technologies. (Published: March 1992)

The U.S. Coal Industry, 1970–1990: Two Decades of Change

This report provides a comprehensive overview of the U.S. coal industry during the past 2 decades, with emphasis on the major changes that occurred, their causes, and their effects. The report presents and analyzes data compiled by EIA on the U.S. coal industry, as well as EIA data on other energy sources and information from non-EIA sources where relevant. These data are used to reveal trends in coal production, consumption, distribution, and prices. Trends in coal mining productivity and employment are also examined, and the profitability of major energy companies' coal operations is tracked over the 1977–90 period. Analysis of the data stresses the impact on the coal industry of major events, such as the oil embargo, technological breakthroughs, and Federal and state laws and regulations affecting the industry. (Published: November 1992)

Service Reports

Federal Energy Subsidies: Direct and Indirect Interventions in Energy Markets

This report, requested by Congress, explores the definition of a subsidy, ultimately incorporating a broad definition of subsidization that includes most governmental actions which had as their function alteration of energy markets by benefiting some group of producers or consumers. The report shows that direct expenditures from the Federal budget account for only a fraction of the total impact of Federal Government intervention in energy markets. The report specifically considers tax incentives received by producers or consumers of various forms of energy; governmental utilities, such as the Tennessee Valley Authority and the Bonneville Power Administration; subsidies received by certain government utilities via tax-exempt municipal bonds; lower interest rates received by rural electric cooperatives; and Government grants for energy research and development activities. The report concludes that it is regulation and not subsidization that has the greatest impact on energy markets. As a result, the report discusses selected energy regulations to illustrate their significant impact. (Published: November 1992.)

Spent Nuclear Fuel Discharges from U.S. Reactors 1990

EIA prepared this report under a memorandum of understanding with the Office of Civilian Radioactive Waste Management in support of their program. The Nuclear Waste Policy Act of 1982, as amended, established the framework for a comprehensive Federal program to manage spent nuclear fuel and high-level radioactive waste. This report covers discharged nuclear fuel assemblies, their shipments and storage, including storage site capacities and inventories as of December 31, 1990, but reflecting data collected and processed by September 3, 1991. The report also presents information and crucial elements of the nuclear fuel cycle: discharges of spent fuel and interim storage of spent fuel. (Published: March 1992.)

State Energy Price Projections for the Residential Sector, 1992–1993

EIA provided this report at the request of the Administrator for Children and Families, U.S. Department of Health and Human Services, which provides state grants to help eligible households meet the costs of home energy use for

space heating or cooling under the Low Income Home Energy Assistance Program. The report provides projections of state-level residential prices for 1992–1993 for electricity, natural gas, heating oil, liquefied petroleum gas, kerosene, and coal. The price projections presented in the report's tables represent trends in relationships between state prices and the U.S. price because it is assumed that an annual state residential energy price can be adequately estimated as a function of the national average price (a volume-weighted average price for the United States). The conclusion is that state prices move more or less in tandem with the movement of the corresponding U.S. average price. (Published: September 1992.)

Water Treatment Technology Costs Associated With Offshore Oil and Gas Production

This report was requested by the Environmental Protection Agency. It was actually a cooperative effort between EIA's Dallas field office and the Environmental Protection Agency, which collects cost data related to its proposed wastewater cleanliness regulations, which will limit the oil and grease content of discharged water produced from oil and gas well operators working in federally controlled waters off the coasts of the United States, including those of Alaska and California. The bulk of the data, however, come from the Gulf of Mexico. The processes investigated include multimedia filtration and hydrocyclones—the two most popular processes—as well as reinjection of produced water, pumping wastewater to shore via pipelines, and erection of platforms for the sole purpose of water treatment. The last three options are costlier and, thus, less likely solutions. (Published: July 1992.)

SPECIAL REPORTS, 1993

EIA analytical reports result from analysts' examinations of current and projected U.S. economic, regulatory, technical, technological, and marketing subjects and their impact on energy supply and demand. They are special, usually one-time, reports. EIA service reports are also analyses, but they are prepared, as the name implies, as a service, upon specific request from other executive branch agencies or Congress. Service reports are often based on assumptions provided by the requestor. During 1993, EIA produced 12 analytical reports and 2 service reports.

Analytical Reports

The Changing Structure of the U.S. Electric Power Industry, 1970–1991

This report provides comprehensive data on the growth of nonutility capacity and generation in the 1980s. By 1991, nonutilities were providing approximately 9 percent of the electricity generated in the United States. The report also explains the legislative, regulatory, economic, and technological changes that contributed to the development of nonutilities. It compares the types of ownership, fuel use, and financial characteristics of nonutilities with those of utilities. (Published: March 1993)

The Changing Structure of the U.S. Coal Industry: An Update

This report documents the change in mine size, number of large companies producing coal, ownership by company type, and foreign ownership from 1976 through 1991. In addition, it contains statistics on coal production and coal reserves concentration ratios. Explanations of the trends over that time period are provided, such as the fact that the primary factor contributing to larger mines and companies was the shift in production toward the West, where low-sulfur coal is produced from thick seams in large surface mining operations. (Published: July 1993)

Drilling Sideways—A Review of Horizontal Well Technology and Its Domestic Application

This report presents a review of the use of horizontal drilling technology in oil exploration, development, and production operations. Horizontal drilling achieved commercial viability during the late 1980s, particularly in the Bakken Shale of North Dakota and the Austin Chalk of Texas. Its successful employment has encouraged the testing of the technology in many domestic geographic regions and geologic situations. Of the three major categories of horizontal drilling, short-, medium-, and long-radius, the medium-radius well has been most widely used and productive. Achievable horizontal bore hole length grew rapidly as familiarity with the technique increased; horizontal displacements have now extended to over 8,000 feet. Some wells have featured multiple horizontal bores. Completion and production techniques have been modified for the horizontal environment, with more change required as the well radius decreases; the specific

geologic environment and production history of the reservoir also determine the completion methods employed. Most horizontal wells have targeted crude oil reservoirs. The commercial viability of horizontal wells for production of natural gas has not been well demonstrated yet, although some horizontal wells have been used to produce coal seam gas. The Department of Energy has provided funding for several experimental horizontal gas wells. (Published: April 1993)

Emissions of Greenhouse Gases in the United States, 1985–1990

This report, mandated by title XVI, section 1605(a) of EPACT, states that research is intensifying to improve our understanding of the role human activities might play in influencing atmospheric concentrations of greenhouse gases, and to identify a range of actions that might reduce the consequences of human actions. Because new scientific findings concerning global climate change may influence every facet of life on this planet, it is being closely followed by government policy-makers, industrial managers, and concerned citizens alike. On the basis of scientific findings of the past few decades, the U.S. Government and the international community at large are now taking steps toward stabilizing greenhouse gas emissions. This report, to be issued annually, contributes to that process by providing estimates of U.S. emissions of the principal greenhouse gases—carbon dioxide, methane, nitrous oxide, chlorofluorocarbons, carbon monoxide, nitrogen oxides, and nonmethane volatile organic compounds. Estimates are for the period 1985 to 1990. Preliminary estimates for 1991 have also been included, whenever data were available. A summary of EIA's estimates of U.S. greenhouse gas emissions appears in Table ES1. Appendix A discusses the uncertainties associated with these estimates. The carbon dioxide estimates presented in this report were used in the President's Global Climate Change Action Plan, issued at the same time. (Published: October 1993)

Energy Policy Act Transportation Rate Study: Availability of Data and Studies

Pursuant to section 1340(c) of EPACT, this report presents the Secretary of Energy's review of data collected by the Federal Government on rates for rail and pipeline transportation of domestic coal, oil, and gas for the years 1988 through 1997, and proposals to develop an adequate data base for each of the fuels on the basis of the data availability review. This report also presents EIA's find-

ings regarding the extent to which any Federal agency is studying the impacts of the Clean Air Act Amendments of 1990 and other Federal policies on the transportation rates and distribution patterns of domestic coal, oil, and gas. While the availability of data differs considerably among the fuels, existing data are found to be generally inadequate to satisfy the requirements of EPACT's section 1340(a). The inadequacy of data thus necessitates collection of additional data, as proposed in the report. (Published: October 1993)

Largest U.S. Oil and Gas Fields

This technical report is part of an EIA series presenting distributions of U.S. crude oil and natural gas resources, developed by using field-level data collected in EIA's annual survey of oil and gas proved reserves. The series' objective is to provide useful information beyond that routinely presented in the EIA annual report on crude oil and natural gas reserves. These special reports also provide oil and gas resource analysts with a fuller understanding of the nature of U.S. crude oil and natural gas occurrence, both at the macro level and with respect to the specific subjects addressed. The series' approach is to integrate EIA's crude oil and natural gas survey data with related data obtained from other authoritative sources and then to present illustrations and analyses of interest to a broad spectrum of energy information users ranging from the general public to oil and gas industry personnel. The report provides the top 100 proved reserves field listings (1991 rankings) in advance of the 1992 EIA reserves report and additionally identifies the top 100 fields in three other categories: 1991 annual production, cumulative production, and estimated ultimate recovery. Also presented are similar listings based on the fields' total hydrocarbons, plus comparisons of the contribution of crude oil versus natural gas, and large fields versus small fields. Finally, the report clearly portrays the Nation's heavy reliance on this relatively small number of fields. (Published: August 1993)

Natural Gas 1992: Issues and Trends

This report is the first in a series of reports analyzing a variety of issues currently affecting the natural gas industry. The report provides up-to-date data on basic measures of activity in the industry, such as production, consumption, and price; it also presents more indepth analyses of several important issues. These issues are: (1) significant changes in laws and regulations affecting the industry (including Federal Energy Regulatory Commission Order 636

and EPACT); (2) trends in supply, focusing on drilling, reserves, production, productive capacity, and wellhead prices; (3) the impact of changes in transportation rate design contained in Order 636; (4) how changes in wellhead prices influence end-use prices seen in the residential, commercial, industrial, and electric utility sectors; (5) the level of recent and proposed interstate pipeline capacity expansions (examined on a regional basis); and (6) the level of activity in the natural gas futures market, a market that is playing an increasingly important role in the industry. (Published: March 1993)

The Public Utility Holding Company Act of 1935: 1935–1992

This report presents an economic and legislative history and analysis of the Public Utility Holding Company Act of 1935. That act was born of events occurring during the Great Depression and continued with only minor alterations until substantially reformed by EPACT. The debate which led to this reform reflects the rapid and dynamic changes which took place in the structure of the electric utilities industry, especially those of the past two decades. Those changes are continuing and may accelerate because of EPACT. The 1935 act shaped the electric industry for over half a century by creating the legal parameters within which it was allowed to develop. By changing the legal framework, EPACT will alter the course which the industry will take. This report and its analysis not only portray the reasons change transpired, but they allow the reader to see the emerging issues to which the industry and those who regulate it must respond. (Published: January 1993)

Renewable Resources in the U.S. Electricity Supply

This report provides an introductory overview of current and long-term forecasted uses of renewable resources in the Nation's electricity marketplace, the largest domestic application of renewable resources today. It is intended for a general audience, but it should be of particular interest to public utility analysts, policy and financial analysts, investment firms, trade associations, Federal and state regulators, and legislators in support of their deliberations and decisions. (Published: March 1993)

U.S. Coal Reserves: An Update by Heat and Sulfur Content

This report provides some of the detailed data necessary to analyze the reliability of future U.S. coal supplies. It

includes information on quality of the coal, accessibility of the known in-ground resource for actual mining, and reserves (the net amount that may be ultimately recoverable from the accessible resource). This report is the first of a series of updates planned with existing state agency data holdings to develop a more valuable coal reserves data base through cooperative efforts. (Published: February 1993)

The U.S. Petroleum Industry: Past as Prologue, 1970–1992

This report focuses on the developments that shaped the domestic petroleum industry and U.S. supply and demand patterns between 1970 and 1992. Investments made during the past 23 years to modernize the industry's operations now provide a base for decisions to be made as the 1990s progress. It also highlights foreign demand and refinery trends. These events are presented in statistical terms in chapter 2 and are described in detail in chapter 3. That is, chapter 2 describes the patterns of change for each component of supply and demand, and briefly touches on the events (fully described in chapter 3) that induced significant change or fluctuation, while chapter 3 presents a chronology of the major petroleum-related events and their consequences. Chapter 3 also describes the actions or reactions of the petroleum industry to the events, and the impact of the events and actions taken on domestic and/or foreign economies. The report is intended to provide background information on the petroleum industry and its history and to act as a reference for those more familiar with the industry. (Published: October 1993)

U.S. Production of Natural Gas from Tight Reservoirs

This report updates EIA's tight gas production information through 1991 and considers further the history and effect on tight gas production of the Federal Government's regulatory and tax policy actions. It also provides some high points of the geologic background needed to understand the nature and location of low-permeability reservoirs. For the purposes of the report, tight gas reservoirs were defined as those that met the Federal Energy Regulatory Commission's definition of tight.

About 90 percent of U.S. natural gas production comes from conventional gas reservoirs. The remainder comes from a variety of nonconventional sources, the most volumetrically important of which consists of so-called tight gas reservoirs. The principal distinction between conventional and tight gas reservoirs lies in their marked

differences of production rate capability. The initial production rates of tight reservoirs, as compared to those of conventional reservoirs, are very low. This often renders them economically marginal. Consequently, some kind of economic incentive must often be present to induce operators to explore for and develop these gas resources. From 1980 through 1992, the Federal Government has allowed operators of new domestic wells drilled into tight gas reservoirs to take either a tax credit on the resulting production or to charge an incentive price that was prescribed relative to the price of oil. The unitary purpose of the Crude Oil Windfall Profits Tax Act's section 29 tax credit and the incentive pricing provided under section 107 of the Natural Gas Policy Act of 1978 was to stimulate exploration for, and development of, these technically difficult and economically marginal nonconventional gas reservoirs, especially during times of low oil prices. (Published: October 1993)

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Single Issues: Domestic: \$2.00 Foreign: \$2.50

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Domestic: \$51.00 Foreign: \$63.75
Single Issue: Domestic: \$2.75 Foreign: \$3.44

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Domestic: \$87.00 Foreign: \$108.75
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Domestic: \$47.00 Foreign: \$58.75
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Domestic: \$71.00 Foreign: \$88.75
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Domestic: \$73.00 Foreign: \$91.25
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GPO Stock No. 061-003-00780-5
Domestic: \$7.00 Foreign: \$8.75

International Energy Annual 1990. February 1992. [DOE/EIA-0219(90)]

GPO Stock No. 061-003-00742-2
Domestic: \$11.00 Foreign: \$13.75

International Energy Annual 1991. December 1992. [DOE/EIA-0219(91)]

GPO Stock No. 061-003-00785-6
Domestic: \$12.00 Foreign: \$15.00

International Energy Outlook 1992. May 1992. [DOE/EIA-0484(92)]

GPO Stock No. 061-003-00750-3
Domestic: \$3.75 Foreign: \$4.69

Inventory of Power Plants in the United States 1991. November 1992. [DOE/EIA-0095(91)]

GPO Stock No. 061-003-00774-0
Domestic: \$23.00 Foreign: \$28.75

Natural Gas Annual 1990 Supplement: Company Profiles. June 1992. [DOE/EIA-0131(90)]

GPO Stock No. 061-003-00755-4
Domestic: \$9.00 Foreign: \$11.25

Natural Gas Annual 1991. December 1992. [DOE/EIA-0131(91)]

GPO Stock No. 061-003-00773-2
Domestic: \$15.00 Foreign: \$18.75

Performance Profiles of Major Energy Producers 1991. December 1992. [DOE/EIA-0206(91)]

GPO Stock No. 061-003-00788-1
Domestic: \$8.50 Foreign: \$10.63

Petroleum Marketing Annual 1991. September 1992. [DOE/EIA-0487(91)]

GPO Stock No. 061-003-00768-6
Domestic: \$24.00 Foreign: \$30.00

Petroleum Supply Annual 1991, Volume 1. June 1992. [DOE/EIA-0340(91)/1]

GPO Stock No. 061-003-00758-9
Domestic: \$11.00 Foreign: \$13.75

Petroleum Supply Annual 1991, Volume 2. June 1992. [DOE/EIA-0340(91)/2]

GPO Stock No. 061-003-00759-7
Domestic: \$31.00 Foreign: \$38.75

Profiles of Foreign Direct Investment in U.S. Energy 1990. April 1992. [DOE/EIA-0466(90)]

GPO Stock No. 061-003-00751-1
Domestic: \$3.25 Foreign: \$4.06

Short-Term Energy Outlook Annual Supplement 1992. June 1992. [DOE/EIA-0202(92)]

GPO Stock No. 061-003-00764-3
Domestic: \$2.75 Foreign: \$3.44

Solar Collector Manufacturing Activities 1990. March 1992. [DOE/EIA-0174(90)]

GPO Stock No. 061-003-00747-3
Domestic: \$4.00 Foreign: \$5.00

Solar Collector Manufacturing Activities 1991. December 1992. [DOE/EIA-0174(91)]

GPO Stock No. 061-003-00782-1
Domestic: \$4.75 Foreign: \$5.94

State Energy Data Report, Consumption Estimates 1960-1990. June 1992. [DOE/EIA-0214(90)]

GPO Stock No. 061-003-00756-2
Domestic: \$26.00 Foreign: \$32.50

State Energy Price and Expenditure Report 1990. September 1992. [DOE/EIA-0376(90)]

GPO Stock No. 061-003-00769-4
Domestic: \$16.00 Foreign: \$20.00

Statistics of Interstate Natural Gas Pipeline Companies 1990. April 1992. [DOE/EIA-0145(90)]

GPO Stock No. 061-003-00752-0
Domestic: \$12.00 Foreign: \$15.00

Supplement to the Annual Energy Outlook 1992. March 1992. [DOE/EIA-0554(92)]

GPO Stock No. 061-003-00748-1

Domestic: \$11.00 Foreign: \$13.75

Uranium Industry Annual 1991. October 1992. [DOE/EIA-0478(91)]

GPO Stock No. 061-003-00771-6

Domestic: \$8.50 Foreign: \$10.63

U.S. Crude Oil, Natural Gas, and Natural Gas Liquids Reserves 1991 Annual Report. December 1992. [DOE/EIA-0216(91)]

GPO Stock No. 061-003-00777-5

Domestic: \$9.50 Foreign: \$11.88

World Nuclear Capacity and Fuel Cycle Requirements 1992. December 1992. [DOE/EIA-0436(92)]

GPO Stock No. 061-003-00181-3

Domestic: \$8.50 Foreign: \$10.63

Biennially, Triennially, and Other

Commercial Buildings Energy Consumption and Expenditure 1989 (triennial). May 1992. [DOE/EIA-0318(89)]

GPO Stock No. 061-003-00753-8

Domestic: \$25.00 Foreign: \$31.25

EIA Publications Style Manual (irregular). December 1992. [DOE/EIA-0415(92)]

Free from NEIC

Electric Trade in the United States 1990 (biennial). December 1992. [DOE/EIA-0531(90)]

GPO Stock No. 061-003-00783-0

Domestic: \$20.00 Foreign: \$25.00

Residential Energy Consumption Survey: Housing Characteristics 1990 (triennial). May 1992. [DOE/EIA-0314(90)]

GPO Stock No. 061-003-00754-6

Domestic: \$23.00 Foreign: \$28.75

Documentation

Documentation of the Resource Allocation and Mine Costing (RAMC) Model. February 1992. [DOE/EIA-M021(92)]

Free from NEIC

International Nuclear Model Personal Computer (PCINM). August 1992. [DOE/EIA-M051(92)]

Free from NEIC

Oil Market Simulation Model User's Guide. August 1992. [DOE/EIA-M028(92)]

Free from NEIC

Reserves Information Gathering System (RIGS) User's Guide. January 1992. [DOE/EIA-M042(91)]

Free from NEIC

World Energy Projection System Model Documentation. June 1992. [DOE/EIA-M050(92)]

Free from NEIC

World Integrated Evaluation System Model Documentation. March 1992. [DOE/EIA-M049]

Free from NEIC

One-Time Publications

Capacity and Service on the Interstate Natural Gas Pipeline System 1990 Regional Profiles and Analyses. July 1992. [DOE/EIA-0556]

GPO Stock No. 061-003-00762-7

Domestic: \$9.50 Foreign: \$11.88

Derived Annual Estimates of Energy: Manufacturing Energy Consumption, 1974-1988. August 1992. [DOE/EIA-0555(92)/3]

GPO Stock No. 061-003-00766-0

Domestic: \$7.00 Foreign: \$8.75

Development of the 1991 Manufacturing Energy Consumption Survey. June 1992. [DOE/EIA-0555(92)/2]

GPO Stock No. 061-003-00757-1

Domestic: \$5.50 Foreign: \$6.88

Geologic Distribution of U.S. Oil and Gas. August 1992. [DOE/EIA-0557]

GPO Stock No. 061-003-00765-1

Domestic: \$9.50 Foreign: \$11.88

Lighting in Commercial Buildings. March 1992. [DOE/EIA-0555(92)/1]

GPO Stock No. 061-003-00749-0

Domestic: \$6.50 Foreign: \$8.13

Pedro User Guide. December 1992. [DOE/EIA-0528(91)]
Free from NEIC

The U.S. Coal Industry, 1970-1990: Two Decades of Change. November 1992. [DOE/EIA-0559]
GPO Stock No. 061-003-00772-4
Domestic: \$7.00 Foreign: \$8.75

U.S. Electricity Trade with Canada and Mexico. January 1992. [DOE/EIA-0553]
GPO Stock No. 061-003-00738-4
Domestic: \$5.00 Foreign: \$6.25

User-Needs for the 1992 Commercial Buildings Energy Consumption Survey. September 1992. [DOE/EIA-0555(92)/4]
GPO Stock No. 061-003-00770-8
Domestic: \$8.50 Foreign: \$10.63

Service Reports

Federal Energy Subsidies: Direct and Indirect Interventions in Energy Markets. November 1992. [DOE/EIA-SR/EMEU/92-02]
Free from NEIC

Spent Nuclear Fuel Discharges from U.S. Reactors 1990. March 1992. [DOE/EIA-SR/CNEAF/92-01]
Free from NEIC

State Energy Price Projections for the Residential Sector, 1992-1993. September 1992. [DOE/EIA-SR/EMEU/92-01]
Free from NEIC

Water Treatment Technology Costs Associated with Off-shore Oil and Gas Production. July 1992. [DOE/EIA-SR/RNGD/92-01]
Free from NEIC

Special Features

There are four categories of special feature articles published by EIA. "Feature Articles," which cover a wide range of energy-related subjects in depth; "Highlights," which summarize the most important information presented in the subject EIA report; "Energy Previews," which provide brief overviews of EIA preliminary energy data on a given topic; and "EIA Data News" items, which present information on recent changes in the scope, design, methodology, and findings of EIA's energy surveys and data

bases. Listed below are the 27 special features published in 1992.

"Comparisons of Independent Statistics on Petroleum Supply" (*Petroleum Supply Monthly*, March 1992)

"Demand, Supply, and Price Outlook for Oxygenated Gasoline, Winter 1992-1993" (*Monthly Energy Review*, August 1992)

"Distillate Fuel Oil Outlook for the 1992-1993 Winter Heating Season" (*Winter Fuels Report*, DOE/EIA-0538(92/93-1) and (92/93-2), October 1992)

"EIA Data News: EIA Statistics on Electric Utility Demand-Side Management" (*Monthly Energy Review*, September 1992)

"EIA Data News: EIA Statistics on Nonutility Power Producers" (*Monthly Energy Review*, October 1992)

"EIA Data News: Oxygenate Data Collection Begins" (*Monthly Energy Review*, May 1992)

"Electric Utility Demand-Side Management" (*Electric Power Monthly*, April 1992)

"Energy Efficiency in the Manufacturing Sector" (*Monthly Energy Review*, December 1992)

"Energy Preview: Residential Energy Consumption and Expenditures, Preliminary Estimates, 1990" (*Monthly Energy Review*, April 1992)

"Highlights: Derived Annual Estimates of Manufacturing Energy Consumption, 1974-1988" (*Monthly Energy Review*, November 1992)

"Highlights: Lighting in Commercial Buildings" (*Monthly Energy Review*, June 1992)

"Imports of Canadian Gas Under Long-Term Contracts" (*Natural Gas Monthly*, December 1992)

"Natural Gas Futures Contract Market—The First 2 Years" (*Natural Gas Monthly*, November 1992)

"Nonutility Power Producers" (*Electric Power Monthly*, April 1992)

"Performance Optimization and Repowering of Generating Units" (*Electric Power Monthly*, August 1992)

"Propane Outlook: Winter 1992-1993" (*Winter Fuels Report*, DOE/EIA-0538(92/93-1) and (92/93-2), October 1992)

"Revisions to Monthly Natural Gas Data" (*Natural Gas Monthly*, March 1992)

"Summary of EIA Oxygenates Operations Identification Survey" (*Weekly Petroleum Status Report*, February 1992)

"Three-Dimensional Seismology: A New Perspective" (*Petroleum Supply Monthly*, December 1992, and *Natural Gas Monthly*, December 1992).

"Timeliness and Accuracy of Petroleum Supply Data" (*Petroleum Supply Monthly*, September 1992)

"The Uranium Industry of the Commonwealth of Independent States" (*Uranium Industry Annual 1991*, October 1992)

"U.S. Natural Gas Imports and Exports—1991" (*Natural Gas Monthly*, August 1992)

"U.S. Petroleum Developments: 1991" (*Petroleum Supply Monthly*, February 1992)

"U.S. Petroleum Supply" (*Petroleum Supply Annual 1991*, Vol. 1, June 1992)

"U.S. Petroleum Trade, 1991" (*Petroleum Supply Monthly*, April 1992)

"U.S. Refining Industry Highlights 1991" (*Petroleum Supply Annual 1991*, Vol. 1, June 1992)

"Wyoming Coal: An Overview" (*Coal Production 1991*, October 1992)

EIA Publications Released for Printing January 1 through December 31, 1993

Daily/Weekly/Monthly

Electric Power Monthly. [DOE/EIA-0226]
GPO Subscription: 761-002-00000-7
Domestic: \$87.00 Foreign: \$108.75
Single Issue: Domestic: \$13.00 Foreign: \$16.25

International Petroleum Statistics Report. [DOE/EIA-0520]
GPO Subscription: 761-018-00000-1
Domestic: \$47.00 Foreign: \$58.75
Single Issue: Domestic: \$4.25 Foreign: \$5.31

Monthly Energy Review. [DOE/EIA-0035]
GPO Subscription: 761-007-00000-9
Domestic: \$77.00 Foreign: \$96.25
Single Issue: Domestic: \$10.00 Foreign: \$12.50

Natural Gas Monthly. [DOE/EIA-0130]
GPO Subscription: 761-008-00000-5
Domestic: \$85.00 Foreign: \$106.25
Single Issue: Domestic: \$10.00 Foreign: \$12.50

Petroleum Marketing Monthly. [DOE/EIA-0380]
GPO Subscription: 761-010-00000-0
Domestic: \$87.00 Foreign: \$108.75
Single Issue: Domestic: \$12.00 Foreign: \$15.00

Petroleum Supply Monthly. [DOE/EIA-0109]
GPO Subscription: 761-001-00000-6
Domestic: \$78.00 Foreign: \$97.50
Single Issue: Domestic: \$11.00 Foreign: \$13.75

Weekly Coal Production. [DOE/EIA-0218]
GPO Subscription: 761-014-00000-5
Domestic: \$77.00 Foreign: \$96.25
Single Issues: Domestic: \$1.75 Foreign: \$2.19

Weekly Petroleum Status Report. [DOE/EIA-0208]
GPO Subscription: 761-015-00000-1
Domestic: \$51.00 Foreign: \$63.75
Single Issue: Domestic: \$2.75 Foreign: \$3.44

Winter Fuels Report (seasonal). [DOE/EIA-0538]
Free from NEIC

Bimonthly

EIA New Releases. [DOE/EIA-0204]
Free from NEIC

Quarterly

Quarterly Coal Report. [DOE/EIA-0121]
GPO Subscription: 761-012-00000-2
Domestic: \$28.00 Foreign: \$35.00
Single Issue: Domestic: \$10.00 Foreign: \$12.50

Short-Term Energy Outlook: Quarterly Projections. [DOE/EIA-0202]
GPO Subscription: 761-013-00000-9
Domestic: \$16.00 Foreign: \$20.00
Single Issue: Domestic: \$4.50 Foreign: \$5.63

U.S. Energy Industry Financial Developments. [DOE/EIA-0543]
GPO Subscription: 761-022-00000-3
Domestic: \$8.00 Foreign: \$10.00
Single Issue: Domestic: \$2.25 Foreign: \$2.81

Annually

Annual Energy Outlook 1993. December 1993. [DOE/EIA-0383(93)]
GPO Stock No. 061-003-00784-8
Domestic: \$9.00 Foreign: \$11.25

Annual Energy Review 1992. June 1993. [DOE/EIA-0384(92)]
GPO Stock No. 061-003-00810-1
Domestic: \$23.00 Foreign: \$28.75

Annual Report to Congress 1992. March 1993. [DOE/EIA-0173(92)]
Free from NEIC

Assumptions for the Annual Energy Outlook 1993. January 1993. [DOE/EIA-0527(93)]
GPO Stock No. 061-003-00789-9
Domestic: \$6.50 Foreign: \$8.13

Coal Production 1992. December 1993. [DOE/EIA-0118(92)]
GPO Stock No. 061-003-00828-3
Domestic: \$7.50 Foreign: \$9.38

Cost and Quality of Fuels for Electric Utility Plants 1992. August 1993. [DOE/EIA-0191(92)]
GPO Stock No. 061-003-00812-7
Domestic: \$11.00 Foreign: \$13.75

Directory of Energy Data Collection Forms. January 1993. [DOE/EIA-0249(92)]
Free from NEIC

Directory of Energy Data Collection Forms. December 1993. [DOE/EIA-0249(93)]
Free from NEIC

Directory of Energy Information Administration Models 1993. June 1993. [DOE/EIA-0293(93)]
Free from NEIC

Domestic Uranium Mining and Milling Industry: 1992 Viability Assessment. December 1993. [DOE/EIA-0477(92)]
GPO Stock No. 061-003-00834-8
Domestic: \$6.00 Foreign: \$7.50

EIA Publications Directory 1992. June 1993. [DOE/EIA-0149(92)]
Free from NEIC

Electric Power Annual 1991. March 1993. [DOE/EIA-0348(91)]
GPO Stock No. 061-003-00794-5
Domestic: \$11.00 Foreign: \$13.75

Electric Sales and Revenue 1991. April 1993. [DOE/EIA-0540(91)]
GPO Stock No. 061-003-00804-6
Domestic: \$14.00 Foreign: \$17.50

Energy Facts 1992. November 1993. [DOE/EIA-0469(92)]
GPO Stock No. 061-003-00829-1
Domestic: \$2.00 Foreign: \$2.50

Energy Information Sheets. December 1993. [DOE/EIA-0578(91)]
Free from NEIC

Financial Statistics of Major U.S. Investor-Owned Electric Utilities 1992. December 1993. [DOE/EIA-0437(92)/1]
GPO Stock No. 061-003-00790-2
Domestic: \$37.00 Foreign: \$46.25

Financial Statistics of Selected Publicly-Owned Electric Utilities 1992. April 1993. [DOE/EIA-0437(92)/2]

GPO Stock No. 061-003-00745-7

Domestic: \$19.00 Foreign: \$23.75

Fuel Oil and Kerosene Sales 1992. November 1993. [DOE/EIA-0535(92)]

GPO Stock No. 061-003-00827-5

Domestic: \$4.50 Foreign: \$5.63

International Energy Outlook 1993. May 1993. [DOE/EIA-0484(93)]

GPO Stock No. 061-003-00805-4

Domestic: \$3.75 Foreign: \$4.69

Inventory of Power Plants in the United States 1992. November 1993. [DOE/EIA-0095(92)]

GPO Stock No. 061-003-00825-9

Domestic: \$25.00 Foreign: \$31.25

Natural Gas Annual 1991 Supplement: Company Profiles. February 1993. [DOE/EIA-0131(91)]

GPO Stock No. 061-003-00791-1

Domestic: \$15.00 Foreign: \$18.75

Natural Gas Annual 1992, Volume 1. December 1993. [DOE/EIA-0131(92)/1]

GPO Stock No. 061-003-00831-1

Domestic: \$17.00 Foreign: \$21.25

Natural Gas Annual 1992, Volume 2. December 1993. [DOE/EIA-0131(92)/2]

GPO Stock No. 061-003-00832-1

Domestic: \$18.00 Foreign: \$22.50

Performance Profiles of Major Energy Producers 1991. December 1993. [DOE/EIA-0206(91)]

GPO Stock No. 061-003-00788-1

Domestic: \$8.50 Foreign: \$10.63

Petroleum Marketing Annual 1992. August 1993. [DOE/EIA-0487(92)]

GPO Stock No. 061-003-00813-5

Domestic: \$25.00 Foreign: \$31.25

Petroleum Supply Annual 1992, Volume 1. June 1993. [DOE/EIA-0340(92)/1]

GPO Stock No. 061-003-00809-7

Domestic: \$12.00 Foreign: \$15.00

Petroleum Supply Annual 1992, Volume 2. June 1993. [DOE/EIA-0340(92)/2]

GPO Stock No. 061-003-00808-9

Domestic: \$31.00 Foreign: \$38.75

Profiles of Foreign Direct Investment in U.S. Energy 1991. April 1993. [DOE/EIA-0466(91)]

GPO Stock No. 061-003-00801-1

Domestic: \$3.25 Foreign: \$4.06

Short-Term Energy Outlook Annual Supplement 1993. August 1993. [DOE/EIA-0202(93)]

GPO Stock No. 061-003-00815-1

Domestic: \$5.00 Foreign: \$6.25

Solar Collector Manufacturing Activities 1992. November 1993. [DOE/EIA-0174(92)]

GPO Stock No. 061-003-00830-5

Domestic: \$5.00 Foreign: \$6.25

State Energy Data Report, Consumption Estimates 1960-1991. June 1993. [DOE/EIA-0214(91)]

GPO Stock No. 061-003-00806-2

Domestic: \$30.00 Foreign: \$37.50

State Energy Price and Expenditure Report 1991. September 1993. [DOE/EIA-0376(91)]

GPO Stock No. 061-003-00818-6

Domestic: \$18.00 Foreign: \$22.50

Statistics of Interstate Natural Gas Pipeline Companies 1991. January 1993. [DOE/EIA-0145(91)]

GPO Stock No. 061-003-00787-2

Domestic: \$14.00 Foreign: \$17.50

Supplement to the Annual Energy Outlook 1993. March 1993. [DOE/EIA-0554(93)]

GPO Stock No. 061-003-00793-7

Domestic: \$17.00 Foreign: \$21.25

Uranium Industry Annual 1992. November 1993. [DOE/EIA-0478(92)]

GPO Stock No. 061-003-00826-7

Domestic: \$9.00 Foreign: \$11.25

Uranium Purchases Report 1992. August 1993. [DOE/EIA-0570(92)]

GPO Stock No. 061-003-00816-0

Domestic: \$1.50 Foreign: \$1.88

U.S. Crude Oil, Natural Gas, and Natural Gas Liquids Reserves 1992 Annual Report. November 1993. [DOE/EIA-0216(92)]

GPO Stock No. 061-003-00822-4

Domestic: \$11.00 Foreign: \$13.75

World Nuclear Capacity and Fuel Cycle Requirements 1993. December 1993. [DOE/EIA-0436(93)]

GPO Stock No. 061-003-00833-0

Domestic: \$8.50 Foreign: \$10.63

Biennially, Triennially, and Other

Household Energy Consumption and Expenditures 1990 (triennial). February 1993. [DOE/EIA-0321(90)]

GPO Stock No. 061-003-00795-3

Domestic: \$22.00 Foreign: \$27.50

Household Energy Consumption and Expenditures 1990 Supplement: Regional. February 1993. [DOE/EIA-0321(90-S)]

GPO Stock No. 061-003-00796-1

Domestic: \$21.00 Foreign: \$26.25

Household Vehicles Energy Consumption 1991 (triennial). December 1993. [DOE/EIA-0464(91)]

GPO Stock No. 061-003-00

Domestic: \$14.00 Foreign: \$

Documentation

GASCAP Wellhead Gas Productive Capacity Model Documentation. June 1993. [DOE/EIA-M052]

Free from NEIC

Motor Gasoline Market, Model Documentation Report. September 1993. [DOE/EIA-M054]

Free from NEIC

NEMS Integrating Module Documentation Report. December 1993. [DOE/EIA-M057]

Free from NEIC

Short-Term Hydroelectric Generation Model. August 1993. [DOE/EIA-M053]

Free from NEIC

Short-Term Integrated Forecasting System 1993 Model Documentation Report. June 1993. [DOE/EIA-M041(93)]

Free from NEIC

One-Time Publications

Assessment of Energy Use in Multibuilding Facilities (of the Energy Consumption Series). August 1993. [DOE/EIA-0555(93)/1]

GPO Stock No. 061-003-00817-8

Domestic: \$7.50 Foreign: \$9.37

Changing Structure of the Electric Power Industry 1970-1991. March 1993. [DOE/EIA-0562]

GPO Stock No. 061-003-00798-8

Domestic: \$6.50 Foreign: \$8.13

Changing Structure of the U.S. Coal Industry: An Update. July 1993. [DOE/EIA-0513(93)]

GPO Stock No. 061-003-00573-0

Domestic: \$3.00 Foreign: \$3.75

Drilling Sideways—A Review of Horizontal Well Technology and Its Domestic Application. April 1993. [DOE/EIA-TR-0565]

GPO Stock No. 061-003-00803-8

Free from NEIC

Emissions of Greenhouse Gases in the United States 1985-1990. October 1993. [DOE/EIA-0573]

GPO Stock No. 061-003-00821-6

Domestic: \$7.00 Foreign: \$8.75

Energy Policy Act Transportation Rate Study Availability of Data and Studies. October 1993. [DOE/EIA-0571]

Domestic: \$5.00 Foreign: \$6.25

Largest U.S. Oil and Gas Fields. August 1993. [DOE/EIA-TR-0567]

GPO Stock No. 061-003-00814-3

Free from NEIC

Proceedings of the National Energy Modeling System Conference. June 1993. [DOE/EIA-0566]

Free from NEIC

Public Utility Holding Company Act of 1935-1992. January 1993. [DOE/EIA-0563]

Free from NEIC

Renewable Resource in the U.S. Electricity Supply. March 1993. [DOE/EIA-0561]

GPO Stock No. 061-003-00797-0

Domestic: \$5.00 Foreign: \$6.25

Study for the 1993 Residential Energy Consumption Survey (of the Energy Consumption Series). September 1993. [DOE/EIA-0555(93/2)]

GPO Stock No. 061-003-00819-4
Domestic: \$13.00 Foreign: \$16.25

U.S. Coal Reserves: An Update by Heat and Sulfur Content. February 1993. [DOE/EIA-0529(92)]

GPO Stock No. 061-003-00792-9
Domestic: \$6.00 Foreign: \$7.50

U.S. Petroleum Industry, The: Past as Prologue 1970-1992. October 1993. [DOE/EIA-0572]

GPO Stock No. 061-003-00824-1
Domestic: \$6.00 Foreign: \$7.50

Service Reports

Spent Nuclear Fuel Discharges from U.S. Reactors 1991. March 1993. [DOE/EIA-SR/CNEAF/93-01]

Free from NEIC

State Energy Price Projections for the Residential Sector, 1993-1994. November 1993.

[DOE/EIA-SR/EMEU/93-01]
Free from NEIC

Special Articles

There are four categories of special articles, or features, published by EIA. "Articles," which cover a wide range of energy-related subjects in depth; "Highlights," which summarize the most important information presented in the subject EIA report; "Energy Previews," which provide brief overviews of EIA preliminary energy data on a given topic; and "EIA Data News" items, which present information on recent changes in the scope, design, methodology, and findings of EIA's energy surveys and data bases. Listed below chronologically are the 38 special articles published in 1993.

"Accuracy of Petroleum Supply Data" (*Petroleum Supply Monthly*, August 1993)

"Changes to Form EIA-782C, 'Monthly Report of Petroleum Products Sold Into States for Consumption'" (*Petroleum Marketing Monthly*, May 1993)

"A Comparison of Selected EIA-782 Data With Other Data Sources" (*Petroleum Marketing Monthly*, August 1993)

"Comparisons of Independent Statistics on Petroleum Supply" (*Petroleum Supply Monthly*, May 1993)

"Decommissioning of U.S. Conventional Uranium Production Centers" (*Uranium Industry Annual*, October 1993)

"Demand, Supply, and Price Outlook for Low-Sulfur Diesel Fuel" (*Monthly Energy Review*, August 1993)

"Distillate Fuel Outlook for Winter 1993-1994" (*Winter Fuels Report*, October 15, 1993)

"Drilling Sideways" (*Petroleum Supply Monthly*, June 1993)

"The Economics of the Clean Air Act Amendments of 1990: Review of the 1992-1993 Oxygenated Motor Gasoline Season" (*Petroleum Supply Monthly*, July 1993; and *Petroleum Marketing Monthly*, August 1993)

"EIA Data News: Natural Gas Transported for the Account of Others" (*Monthly Energy Review*, February 1993)

"Electric Utility Demand-Side Management and Regulatory Effects" (*Electric Power Monthly*, November 1993)

"Energy Preview: Manufacturing Energy Consumption Survey, Preliminary Estimates, 1991" (*Monthly Energy Review*, September 1993)

"Energy Preview: Residential Transportation Energy Consumption Survey, Preliminary Estimates, 1991" (*Monthly Energy Review*, January 1993)

"The Expanding Role of Underground Storage" (*Natural Gas Monthly*, October 1993)

"Federal and Indian Coal Lands: A Growing Source of Energy and Revenue" (*Coal Production 1992*, October 1993)

"Highlights: Assessment of Energy Use in Multibuilding Facilities" (*Monthly Energy Review*, October 1993)

"Highlights: The Changing Structure of the U.S. Coal Industry: An Update" (*Monthly Energy Review*, November 1993)

"Highlights: Emissions of Greenhouse Gases in the United States 1985-1990" (*Monthly Energy Review*, December 1993)

"Highlights: Federal Energy Subsidies: Direct and Indirect Interventions in Energy Markets" (*Monthly Energy Review*, July 1993)

"Highlights: Household Energy Consumption and Expenditures 1990" (*Monthly Energy Review*, August 1993)

"Highlights: International Energy Outlook 1993" (*Monthly Energy Review*, October 1993)

"Highlights: Natural Gas 1992: Issues and Trends" (*Natural Gas Monthly*, March 1993)

"Highlights: Natural Gas 1992: Issues and Trends" (*Monthly Energy Review*, September 1993)

"Improvements in Nuclear Power Plant Capacity Factors" (*Electric Power Monthly*, February 1993)

"Low Sulfur Diesel: Requirements and Impacts" (*Petroleum Marketing Monthly*, December 1993)

"Midwest Propane Markets, 1992–1993, A Mid-Season Assessment" (*Winter Fuels Report*, February 1993)

"Municipal Solid Waste in the U.S. Energy Supply" (*Electric Power Monthly*, October 1993)

"Natural Gas Productive Capacity" (*Natural Gas Monthly*, March 1993)

"Natural Gas in Transition" (*Short-Term Energy Outlook*, Third Quarter, August 1993)

"Propane Outlook for Winter 1993–1994" (*Petroleum Marketing Monthly*, November 1993)

"Revisions to Monthly Natural Gas Data" (*Natural Gas Monthly*, April 1993)

"Sales of Fuel Oil and Kerosene in 1992" (*Petroleum Marketing Monthly*, December 1993)

"Strategies for Compliance With Phase I of the Clean Air Act Amendments of 1990" (*Short-Term Energy Outlook*, Third Quarter, August 1993)

"Summer 1993 Motor Gasoline Outlook" (*Petroleum Supply Monthly*, April 1993; and *Petroleum Marketing Monthly*, May 1993)

"U.S. Natural Gas Imports and Exports–1992" (*Natural Gas Monthly*, August 1993)

"U.S. Petroleum Developments: 1992" (*Petroleum Supply Annual 1992, Volume 1*, May 1993)

"U.S. Production of Natural Gas from Tight Reservoirs" (*Natural Gas Monthly*, October 1993)

"Will the World Need Iraqi Oil Anytime Soon?" (*Short-Term Energy Outlook*, Third Quarter, August 1993)

CHAPTER 7

POWER MARKETING AND ENERGY PRODUCTION

INTRODUCTION

DOE markets energy in three forms: electricity produced by Federal hydropower projects and acquired from thermal, conservation, and renewable resources under the five power marketing administrations (PMAs); enriched uranium produced for domestic and international customers; and crude oil, petroleum products, and natural gas produced from the Naval Petroleum Reserves (NPRs). Table 7-1 summarizes estimated gross energy production costs and revenues for 1992 and 1993.

Revenues of the PMAs are generally deposited directly into the U.S. Treasury, as are revenues from the sale of crude oil and petroleum products from the NPRs. These revenues normally do not reduce the Department's need for budget authority to support program operations. However, revenues of the Bonneville Power Administration (BPA) and the Western Area Power Administration's (Western's) Colorado River Basins Power Marketing Fund projects are deposited into revolving funds that are used to support those programs directly. Revenues from the sale of enriched uranium are used to offset production costs directly. Also, the Western and Southwestern Power Administrations use power revenues or reimbursements in certain cases to finance purchased power and transmission expense, thus reducing the need for budget authority. Alaska also offsets budget authority requirements by using revenues to fund substation operations and transmission line maintenance.

The Strategic Petroleum Reserve is not considered in this chapter because it does not ordinarily produce revenues. Its inventory of oil is to be sold to petroleum refiners only in the event of a major supply disruption.

POWER MARKETING

The Federal power marketing program began in the early 1900s. Projects under the Department of the Interior's Bureau of Reclamation were developed to produce hydroelectric power for use in pumping irrigation water. In 1906, the Secretary of the Interior was authorized to market power produced at reclamation projects in excess of project needs. Proceeds from the sale of such power were used to repay the Government's investment in the projects.

Growing demand for irrigation, navigation, flood control, and rural electrification resulted in an expansion of Federal multipurpose water projects. By 1977, four PMAs and the Bureau of Reclamation were marketing power from such projects. The Department of Energy Organization Act of 1977 created a fifth PMA, Western Area, and transferred the other four—Alaska, Bonneville, Southeastern, and Southwestern Power Administrations—to DOE, while preserving them as distinct entities. Each has its own geographic boundaries, system of projects, statutory authorities, operation and maintenance responsibilities, and individual statutory history. The geographical boundaries of the PMAs are shown in Figure 7-1.

The five PMAs market the power generated at all Federal multipurpose water projects except those under the jurisdiction of the Tennessee Valley Authority. To carry out their responsibilities, the administrations contract for the sale and purchase of power and transmission service; develop rates; construct, operate, and maintain transmission lines, substations, switchyards, and attendant facilities; conduct appropriate energy conservation programs; and oversee required environmental reviews pertaining to such activities. In addition, Alaska operates and maintains

Table 7-1—Gross energy production costs and revenues, 1992 and 1993

Category	1992	1993
(millions of dollars)		
Production and distribution costs		
Power marketing		
Alaska Power Administration	3.7	3.7
Bonneville Power Administration	2,202.4	2,239.4
Southeastern Power Administration	119.6	133.1
Southwestern Power Administration	55.4	52.7
Western Area Power Administration	645.0	568.0
Subtotal	3,026.1	2,996.9
Uranium enrichment	1,268.1	1,346.6
Naval Petroleum Reserves	202.2	207.0
Total	4,496.4	4,550.5
Revenues		
Power marketing		
Alaska Power Administration	9.4	10.2
Bonneville Power Administration	1,928.8	1,942.5
Southeastern Power Administration	155.3	160.5
Southwestern Power Administration	103.0	115.7
Western Area Power Administration	757.7	737.3
Subtotal	2,954.2	2,966.2
Uranium enrichment	1,408.4	1,450.4
Naval Petroleum Reserves	473.0	440.0
Total	4,835.6	4,856.6

the Federal hydroelectric generation facilities at its two projects. The Pacific Northwest Electric Power Planning and Conservation Act (Northwest Power Act; Public Law 96-501; December 5, 1980) requires BPA to acquire resources to meet the electric load growth of the requesting utilities while protecting and enhancing fish and wildlife that may be affected by the development and operation of Federal hydroelectric projects on the Columbia River and its tributaries.

The PMAs also use transmission facilities of other utilities to "wheel" power to end-use customers. The energy output of PMA hydroelectric projects constitutes approximately 45 percent of the Nation's hydropower production and 6 percent of the Nation's total electric power. To deliver power to their customers, located in 33 states, the PMAs operate and maintain approximately 32,900 circuit miles (53,000 kilometers) of high-voltage transmission lines and related facilities. These include switchyards, substations, and dispatch centers. Tables 7-2 and 7-3 present primary system statistics for 1992 and 1993 and the customer breakdown for the five administrations.

Sales and Revenues

The PMAs earn revenues primarily from the sale of power and related utility services (for example, wheeling power, firming nonfirm power) to wholesale electric utility customers. These revenues are intended to offset annual operation and maintenance costs and repay with interest the capital investment in the power programs. Revenues from the sale of electric power generated at some Federal hydroelectric projects also help meet capital repayment to the U.S. Treasury for irrigation features that are beyond the irrigators' ability to repay.

Some PMAs provide substantial amounts of power to military bases, DOE national laboratories, and other Federal facilities. These power sales reduce operating expenses and, hence, budget authority requirements for such facilities.

Each PMA establishes rates for its discrete systems or for its major projects. Law and longstanding policy require that power be priced at the lowest possible rate con-

7-1. Areas of the United States served by the five power marketing administrations—Alaska Power Administration, Bonneville Power Administration, Southeastern Power Administration, Southwestern Power Administration, and Western Area Power Administration.

sistent with sound business principles and, generally, that the administrations give preference in the sale of power to public bodies and rural electric cooperatives. BPA is further mandated to extend the availability of low-cost Federal system power to the residential and small farm customers of investor-owned and publicly owned utilities that obtain power within BPA's service area.

Revenues, expenses, interest, and repayments through September 30, 1992, are summarized in Tables 7-4 and 7-5. Four of the five PMAs deposit most of their revenues from power sales in the U.S. Treasury as proprietary receipts and fund their administrations with annual appropriations. The self-financed BPA deposits its revenues in a revolving account that funds its programs directly. PMA power and transmission rate adjustments for October 1, 1991, through September 30, 1993, are shown in Table 7-6.

Through 1992, \$5.0 billion of the Federal investments in power generation and transmission facilities had been repaid, and through 1993, \$5.4 billion, as well as \$9.2 billion in interest on all unpaid investments. As of the end of 1993, the PMAs were still responsible for repaying \$2.2 billion in irrigation investments that are assigned to power users for repayment. The net Federal investment to be repaid by PMA power revenues increased by \$1.1 billion, from \$14.1 billion at the end of 1991 to \$15.2 billion at the end of 1993. Net Federal investment to be repaid increased by \$872 million for BPA and \$5 million for the Alaska Power Administration, and decreased by \$48 million for Southwestern, held constant for Southeastern, and increased by \$420 million for Western from the end of 1991 to the end of 1993.

Table 7-2a—Primary statistics for the power marketing administrations, 1992

Power marketing administration	Transmission lines, miles (kilometers)		No. of substations, all voltages	No. of powerplants, ^a all types	Maximum operating capability, megawatts	Revenues, millions of dollars	Sales, billions of kilowatthours (billions of megajoules)	
Alaska	89	(143)	5	2	108	9.4	0.4	(1.4)
Bonneville	14,799	(23,817)	387	30	22,932	1,928.8	85.2	(306.7)
Southeastern	—	(—)	—	22	3,047	155.3	6.9	(24.8)
Southwestern	1,380	(2,220)	24	24	2,158	103.0	6.6	(23.8)
Western Area	16,454	(26,475)	268	53	10,486	757.7	34.0	(122.0)
Total	32,722	(52,655)	684	131	38,731	2,954.2	133.1	(478.7)

^aPlants are owned by the Federal Government and operated primarily by the U.S. Army Corps of Engineers and the Bureau of Reclamation, except for those operated by the Alaska Power Administration. Production is marketed by the power marketing administrations.

Table 7-2b—Primary statistics for the power marketing administrations, 1993

Power marketing administration	Transmission lines, miles (kilometers)		No. of substations, all voltages	No. of powerplants, ^a all types	Maximum operating capability, megawatts	Estimated revenues, millions of dollars	Sales, billions of kilowatthours (billions of megajoules)	
Alaska	89	(143)	4	2	108	10.2	0.4	(1.5)
Bonneville	14,799	(23,817)	387	30	22,932	1,942.5	85.2	(306.7)
Southeastern	—	(—)	—	22	3,047	152.0	8.7	(31.3)
Southwestern	1,380	(2,220)	24	24	2,158	115.5	8.1	(29.1)
Western Area	16,266	(26,172)	271	55	10,508	819.7	30.5	(109.8)
Total	32,534	(52,352)	686	133	38,753	3,039.9	132.9	(478.4)

^aPlants are owned by the Federal Government and operated primarily by the U.S. Army Corps of Engineers and the Bureau of Reclamation, except for those operated by the Alaska Power Administration. Production is marketed by the power marketing administrations.

Activities

All the PMAs use open public processes to encourage public participation in important decisions regarding power allocations, rate adjustments, and service extensions. BPA's procedural rules relating to its ratemaking are published in the *Federal Register* (51 FR 7611, March 5, 1986). In accordance with the Northwest Power Act, the BPA Ad-

ministrator submits the BPA rate proposal to the Federal Energy Regulatory Commission (FERC) for confirmation and approval. Also under that legislation, BPA has initiated a public involvement process that has been well received in the Pacific Northwest marketing area.

The procedures for public participation in adjustments of power rates of the other PMAs are published in the Code of Federal Regulations (10 CFR 903.1). In contrast to BPA, the other PMAs usually submit their proposed rates to DOE

Table 7-3a—Customer breakdown for the power marketing administrations, 1992

Power marketing administration	No. of customers					Total
	Municipals	Cooperatives	Investor-owned	Federal/state/county	Industrial/others	
Alaska	1	2	1	1	0	5
Bonneville	79	56	11	8	16	170
Southeastern	162	127	1	3	0	293
Southwestern	78	11	2	4	0	95
Western Area	278	45	23	187	79	612
Total	598	241	38	203	95	1,175

Table 7-3b—Customer breakdown for the power marketing administrations, 1993

Power marketing administration	No. of customers					Total
	Municipals	Cooperatives	Investor-owned	Federal/state/county	Industrial/others	
Alaska	1	2	1	1	0	5
Bonneville	87	56	14	8	16	181
Southeastern	162	127	5	3	0	297
Southwestern	79	11	2	4	0	96
Western Area	275	47	23	184	80	613
Total	604	243	45	200	96	1,192

Headquarters before sending them to FERC. A secretarial officer, in accordance with an applicable delegation of authority, places such rates into effect on an interim basis, pending FERC's final confirmation and approval. The Deputy Secretary of Energy is the Department's officer currently authorized to place the interim rates into effect.

From October 1, 1991, to September 30, 1993, power and transmission rate increases of approximately \$154 million were placed into effect on an interim or final basis.

Alaska Power Administration

The Alaska Power Administration (APA) operates, maintains, and markets power from Alaska's two Federal hydroelectric projects: the 30-megawatt Eklutna Project, which provides approximately 5 percent of the electric energy needs of the Anchorage and Matanuska Valley

areas, and the 78-megawatt Snettisham Project, which provides nearly 80 percent of the power for the Juneau area. Energy sales from the two projects totaled 368 million kilowatthours (1.32 million gigajoules) in 1992.

Eklutna and Snettisham were authorized and constructed as single-purpose hydroelectric projects to promote economic development, with all of the Federal investment allocated to power. Subsequent state and local investments have brought about important new uses of project lands and water, including salmon hatcheries at each project and important recreation facilities at Eklutna Lake. The Municipality of Anchorage operates the Eklutna Municipal Water Project, drawing water from Eklutna Lake to provide for long-term municipal and industrial water supplies. Figure 7-2 is a photograph of Long Lake at the Snettisham Project, one of three glacier-fed lakes that provide hydroenergy for the APA system.

Table 7-4—Current status of revenues, expenses, interest, and repayment of Federal investment cumulatively through September 30, 1993, of the five power marketing administrations

Category	Cumulatively through 1993 (millions of dollars)	Category	Cumulatively through 1993 (millions of dollars)
Revenues		Cumulative repayable investment	
Alaska Power Administration	144	Power	
Bonneville Power Administration	34,723 ^a	Alaska Power Administration	205
Southeastern Power Administration	2,324	Bonneville Power Administration	10,458 ^a
Southwestern Power Administration	2,042	Southeastern Power Administration	1,441
Western Area Power Administration	11,319 ^b	Southwestern Power Administration	997
Total	50,552	Western Area Power Administration	4,191 ^d
Expenses		Subtotal	17,292
Operation and maintenance		Irrigation assistance	
Alaska Power Administration	52	Bonneville Power Administration	769 ^a
Bonneville Power Administration	5,572 ^a	Western Area Power Administration	1,401
Southeastern Power Administration	1,043	Other capital	
Southwestern Power Administration	683	Bonneville Power Administration	1,033 ^a
Western Area Power Administration	4,311	Western Area Power Administration	39
Subtotal	11,661	Subtotal	3,242
Purchased power		Total	20,534
Alaska Power Administration	0		
Bonneville Power Administration	20,825 ^a	Less cumulative amortization	
Southeastern Power Administration	65	Alaska Power Administration	39
Southwestern Power Administration	520	Bonneville Power Administration	2,412 ^a
Western Area Power Administration	3,013	Southeastern Power Administration	435
Subtotal	24,423	Southwestern Power Administration	298
Interest		Western Area Power Administration	2,198 ^c
Alaska Power Administration	53	Total	5,382
Bonneville Power Administration	5,914 ^a		
Southeastern Power Administration	781	Unamortized investment	
Southwestern Power Administration	536	Alaska Power Administration	166
Western Area Power Administration	1,911	Bonneville Power Administration	9,848 ^a
Subtotal	9,195	Southeastern Power Administration	1,007
Total	45,279	Southwestern Power Administration	699
		Western Area Power Administration	3,433 ^d
Remainder applied to, or		Total	15,153
available for, amortization			
Alaska Power Administration	39		
Bonneville Power Administration	2,412 ^a		
Southeastern Power Administration	435		
Southwestern Power Administration	298		
Western Area Power Administration	2,198 ^c		
Total	5,382		

^a Dollar amounts cash actually transferred.^b Includes \$109 million of revenue transferred to the Bureau of Reclamation.^c Western has deferred payment on \$228 million of expenses because of poor water conditions for the past 7 years. These deferred expenses will be repaid with interest. Western has raised its power rates to accelerate repayment of these deferred expenses.^d These investments include both Federal and non-Federal power investments.

**Table 7-5a—Repayment of Federal investments through September 30, 1992,
of the five power marketing administrations**

Power marketing administration	Cumulative		Actual 1992	
	Repayable investment	Repaid	Repaid	Interest
(millions of dollars)				
Alaska	200	38	1.0	5.0
Bonneville	11,383	2,163	248.0	314.0
Southeastern	1,435	387	35.7	42.7
Southwestern	993	252	28.0	20.0
Western Area	5,334 ^a	2,114	16.0	131.5
Total	19,345	4,954	328.7	513.2

^aThe figure for Western reflects total investment.

**Table 7-5b—Repayment of Federal investments through September 30, 1993,
of the five power marketing administrations**

Power marketing administration	Cumulative		1993	
	Repayable investment	Repaid	Repaid	Interest
(millions of dollars)				
Alaska	205	39	2	5
Bonneville	12,260	2,412	249	360
Southeastern	1,441	435	36	44
Southwestern	997	298	46	18
Western Area	5,631 ^a	2,198	25	162
Total	20,534	5,382	358	589

^aThe figure for Western reflects total investment.

During 1993, APA collected \$10.2 million in gross operating revenue from energy sales; of this amount, \$1.7 million was applied toward debt repayment. As of the end of 1993, the Administration's revenue had repaid to the Treasury \$39 million (19 percent) of the \$205 million investment. Total cumulative operating revenue through 1993 was \$144 million, of which \$52 million was provided for operation and maintenance, \$53 million for

interest, and \$39 million for repayment of investment in power facilities.

Work continued on the proposed divestiture of APA projects. DOE believes that ownership and control within Alaska are most appropriate for these projects. A legislative proposal authorizing the sale of the Eklutna and Snettisham Projects was submitted for congressional consideration in 1993.

**Table 7-6—Power marketing administrations' power and transmission rate adjustments,
October 1, 1991–September 30, 1993**

Effective date	Power marketing administration	Affected area/project	Incremental amount (millions of dollars)	Incremental change (%)
October 1, 1991	Alaska	Snettisham Project	0.7	11.0
October 1, 1991	Southeastern	Georgia-Alabama-South Carolina System	17.977	21.0
October 1, 1991	Southwestern	Integrated System	7.419	8.6
October 1, 1991	Western	Salt Lake City Area Integrated Projects	30.300	46.0
October 1, 1991	Western	Pick-Sloan Missouri Basin Program (Eastern Division)	12.2 (power)	19.0
October 1, 1991	Western	Loveland Area Projects	5.4 (power) 2.9	20.0 62.0
December 1, 1991	Western	Salt Lake City Area Integrated	11.6 (power)	11.7
April 1, 1992	Southwestern	Integrated System	4.946	5.7
April 20, 1992	Southeastern	Jim Woodruff	3.152	120.0
July 1, 1992	Western	Colorago River Storage	0.182	4.0
July 1, 1992	Western	Salt Lake City Area Integrated	3.3 (power)	3.2
January 1, 1993	Western	Boulder Canyon	13.4 (power)	37.7
April 1, 1993	Southwestern	Sam Rayburn Dam	0.266	14.7
April 1, 1993	Southwestern	Robert D. Willis	-0.124	-30.4
May 1, 1993	Western	Central Valley	23.8	8.7
June 7, 1993	Western	Falcon-Amistad	0.0	0.0
August 1, 1993	Western	Pacific Northwest-Southwest Intertie	16.6 (transmission)	80.0

Bonneville Power Administration

Congress created BPA in 1937, and the administration today markets about half the electricity consumed in the

Pacific Northwest and nearly 80 percent of the region's high-voltage transmission, including the northern segment of the Pacific Intertie with the Pacific Southwest. BPA owns and operates 14,800 circuit miles (38,000 kilometers)

7-2. Long Lake, at APA's Snettisham Project, is one of three glacier-fed lakes that provide hydroenergy for APA, the only power marketing administration that generates its own power. Two of the lakes have natural dams and all are in mountainous settings.

7-3. The Columbia River Gorge near Bonneville Dam.

of high-voltage transmission line and 389 substations. It uses revenues from the sale of power and transmission services to recover its expenses and to repay—with interest—the Federal investment in power generation and transmission facilities in the Pacific Northwest as well as assigned irrigation assistance. Figure 7-3 shows the Columbia River Gorge near the Bonneville Dam.

The total remaining debt at the end of 1993 was \$6.9 billion. Another \$7.0 billion is owed to non-Federal sources for financing three Washington Public Power Supply System nuclear projects, the Federal Columbia River Power System's share of the Trojan nuclear plant, and other investments. On January 4, 1993, Portland General Electric's board of directors recommended permanent closure of Trojan. BPA expects to make short-term purchases to replace its 30-percent share.

The Federal Energy Regulatory Commission (FERC) reviews rates established by the BPA Administrator under section 7(a) of the Pacific Northwest Power Planning and Conservation Act for compliance with three standards: (1) the rates must be sufficient to ensure repayment of the Federal investment in the Federal Columbia River Power System over a reasonable number of years after first meeting the Administrator's other costs; (2) the rates must be based upon the Administrator's total system costs; and (3) with respect to transmission rates, the rates must equitably allocate the costs of the Federal transmission system between Federal and non-Federal power utilizing such system (18 CFR 300.21 (c)).

Response to Regional Legislation

BPA started implementing the Regional Power Act in 1981. The administration's added responsibilities under the act include multisector energy conservation programs, residential power exchanges with utilities, resource planning and acquisition, funding of fish and wildlife programs, expanded state and local government assistance programs, liaison and funding for the Northwest Power Planning Council, and BPA's public involvement program.

The Drought

Water in the Federal Columbia River Power System has been extremely low for 4 of the last 5 years. In January and February of 1993 alone, drought conditions cost BPA more than \$186 million. Cold temperatures and low precipitation increased demand for electricity and reduced inflows into Federal reservoirs.

Over the past decade, streamflows have fallen below annual averages by 71 million acre-feet (87,579 million cubic meters), the equivalent of more than half a year's total runoff. The 50-year average for January-through-July streamflow is 107 million acre-feet (131,985 million cubic meters). In 1992, the streamflow was 70 million acre-feet (86,345 million cubic meters); for 1993, 88 million acre-feet (108,548 cubic meters). These worsening water conditions during the last decade, clearly evident in Figure 7-4, have weakened BPA's financial condition.

7-4. Drought in the Northwest continues to impair BPA's financial condition.

BPA began purchasing power in late 1992 and continued to make such purchases in 1993. The 1992 power purchases totaled \$136 million. In 1993, BPA spent \$222 million on power purchases, while only \$91 million had been budgeted. The reduction in power sales to the Southwest and to BPA's direct-service industrial customers (principally, aluminum plants) also reduced revenues, hurting BPA in two ways. First, an 11.5-percent rate increase that had been proposed in January for 1994-1995 would have doubled had the Administrator not acted to reduce the increase to 15 percent. Second, the agency's financial reserves, which were approaching \$1 billion 2 years ago, were reduced to \$221 million as of September 30, 1993.

Bonneville had embarked upon a function-by-function review and a competitiveness project as a midterm method of meeting customer criticism of the proposed 11.5-percent rate increase over the next several years, but, as a result of the continued deterioration of streamflows, the Administrator proposed in late March 1993 additional short-term actions to meet the sharp reduction in revenues. These actions are designed to ensure that BPA meets its U.S. Treasury payment and decreases the rate increase. These reductions include both administrative cuts and 5- to 25-percent program reductions or deferrals.

The 1994-1995 Rate Case

BPA implemented a rate increase that took effect October 1, 1993. Rates to public agency and rural cooperative customers rose an average of 15.7 percent. The rate increase to aluminum industries was almost 18 percent, the higher

increase due to their variable rate structure. The rate increase is expected to raise an additional \$541 million over the 1994-1995 rate period.

The rate increase provides for net revenues to average about \$79 million for the 1994-1995 rate period. Additional protection is provided by an Interim Rate Adjustment, which could provide up to \$250 million in 1995, should end-of-1994 financial reserves fall below \$145 million. The new rates, together with the interim adjustment, provide for an 85-percent probability of meeting BPA's U.S. Treasury payments on time and in full.

As of September 30, 1992, BPA had financed nearly 60 percent of its investments in the Federal Columbia River Power System from the U.S. Treasury through Federal appropriations and issuance of bonds. BPA investments totaled nearly \$16 billion. The Federal appropriations had to be paid back from revenues at an interest rate of 3.5 percent. In 1993, Treasury bonds had a weighted average interest rate of 7.9 percent.

Function-by-Function Review

BPA has more than 3,700 Federal employees and another 1,000 contractor employees. More than a year ago, BPA management agreed with the Department of Energy managers on the need to review BPA's use of manpower and other resources to determine the most efficient use of full-time equivalencies and the most cost-effective mix of contractor and Federal employment. In October 1992, the BPA Executive Committee called for a function-by-function analysis to be conducted during the next 3 to 5 years.

The Competitiveness Project

By February 1993, BPA management had completed discussions with customers and sharpened the function-by-function idea into a more intensive quality management exercise that provided a "strategic overlay." Instead of an operating efficiency review, the customers were concerned with policy, program, design, and transmission development. From discussions, BPA concluded that customers wanted to create a strategic overlay by studying 10 to 15 functional areas; the goal would be a much more market-driven, cost-focused, customer- and results-oriented organization.

Fish and Wildlife

Over the years, BPA has paid more than \$700 million for hatcheries and fish ladders as a result of the Federal system impacts (Figure 7-5). Since passage of the Regional

7-5. Hatcheries are an important element of BPA's fish and wildlife program.

Power Act in 1980, ratepayers have paid an additional \$1.1 billion for the Regional Power Council's Fish and Wildlife Program. Unlike earlier investments, investments under the Regional Power Act have addressed almost every element of the Columbia Basin's fish and wildlife resources, including substantial changes in hydro system operations to protect fish and reduce power generation.

In 1992, the National Marine Fisheries Service listed runs of Snake River sockeye and chinook salmon under the Endangered Species Act, refocusing BPA and the region's effort toward protection and enhancement of wild stocks. While awaiting a formal recovery plan, BPA delivered the National Marine Fisheries Service a biological assessment to make sure its water management actions for 1992 and 1993 would not jeopardize the listed wild salmon stocks. Based on recommendations from the Council and the National Marine Fisheries Service, BPA adjusted its power operations, and almost doubled the water budget, sending more water down the Columbia River to speed the out-migration of young salmon. BPA's total commitment to fish and wildlife (see Figure 7-6)—direct expenditures and foregone revenues—was more than \$300 million in 1993.

Third Alternating Current Intertie

Work on the third alternating current (AC) intertie, which will increase the capacity of the existing AC lines by 1,600 megawatts and expand the ties to northern California, continued at a pace to meet its target completion date of November 1993. BPA signed a preliminary agreement

7-6. Fish passing through a BPA dam in an area designed for visitor viewing.

on sharing the line with non-Federal parties in 1992, and by early 1993 the 11 utilities that had originally expressed an interest were reduced to 6. The remaining utilities are Puget Sound Power and Light, Eugene Water and Electric Board, Pacific Northwest Generating Cooperative, Seattle City Light, Snohomish Public Utility District, Tacoma City Light, and PacifiCorp. The agreements are expected to be executed by May 1994, so that BPA will begin receiving payments by June 1994.

Transmission Improvements

In Northwestern Washington, BPA is planning a transmission project with Puget Sound Power and Light Company that will improve the reliability of the area's power system and increase capacity on an intertie between the United States and Canada. BPA also is completing a project

in central Washington that will increase transfer capability into the Puget Sound area from the east and will help keep voltages stable, even in a winter power emergency. Also, local voltage control devices have been installed in both the Puget Sound and Portland, Oregon, areas to provide voltage support and improve reliability for west side load service. Figure 7-7 shows a substation undergoing technical improvements to increase system reliability.

A transmission project is being planned between Spokane and Grand Coulee that will increase east-to-west transfer capacity and eliminate present transmission restrictions during periods of high eastern generation.

Power Outlook

A combination of low water conditions and load growth eliminated the regional power surplus that had characterized previous years. BPA's 1992 Resource Program laid out a plan to meet its share of the regional planning council's power plan. BPA began seeking low-cost, low-risk resources that can be captured with minimal adverse environmental impact.

7-7. BPA's Slatt substation underwent major technical improvements to ensure a more reliable power system.

The plan calls for BPA to acquire an additional 660 average megawatts of conservation and 120 average megawatts of efficiency improvements at Federal hydropower projects by 2003. BPA achieves verifiable energy savings in the residential, commercial, industrial, and agricultural sectors through conservation programs operated by its retail utility customers.

BPA's 1992 Resource Program calls for an additional 400 average megawatts from sources other than conservation and currently planned resources. Cogeneration and renewable resources such as small hydro, geothermal, wind and solar energy, and combustion turbines all may play a role. In 1993, BPA signed an agreement to buy the output of a 240-megawatt gas-fired combustion turbine near Tacoma, Washington. The Resource Program also includes a contingency program calling for the purchase of options on projects totaling 1,050 average megawatts. The contingency resources could be acquired to meet higher levels of load growth.

1992 Revenues and Expenses

In 1992, expenses exceeded revenues by \$274 million. The Federal Columbia River Power System's revenues decreased by \$291 million to \$1.9 billion, down 13 percent from 1991. Drought conditions were the main reason. The year 1992 was the region's third driest in the past 55 years, and 1992-1993 is the lowest 2-year period on record for the fully developed system. Revenues from sale of power decreased by \$166 million last year, approximately 9 percent. Firm power sales to private and public utilities held steady, but aluminum company revenues dropped by \$175 million, or 30 percent, to \$408 million in 1992. Low prices for aluminum, on which BPA's variable rate is based, accounted for most of the reduction. Public utility sales, BPA's largest customer group, rose \$17 million to \$966 million. Low streamflows also meant reduced sales outside the region; they declined to \$60 million, down \$136 million from the previous year.

On the other hand, the Federal Columbia River Power System's operating and net interest expenses in 1992 were up \$407 million from 1991, to \$2.2 billion. The largest contributing factor by far was BPA's expenditure of \$146 million on power purchases, almost five times what it had spent in 1991. As indicated at the outset, BPA needed to buy more power in 1992 to compensate for low water conditions and unplanned outages at nuclear powerplants and to provide adequate flows for fish. Expenses for fish and wildlife measures more than doubled in 1992, to \$66 million, primarily to comply with the Endangered Species Act.

The depletion of financial reserves began in 1992; in each of the prior 4 years, BPA experienced positive and growing net revenues.

1993 Revenues and Expenses

In 1993, expenses exceeded revenues by \$298 million. The Federal Columbia River Power System's revenues were \$1.94 billion, an increase of \$14 million over 1992 revenues. Drought conditions persisted from 1992 through 1993. The January-through-July runoff period was the 17th lowest of the 65-year record, and the 1992-1993 2-year combined runoff periods were the seventh lowest on record. Revenues from sales to aluminum companies continued to fall in 1993, down about \$54 million from 1992, and \$210 million below the projections used to set rates in 1991. Low prices of aluminum, on which BPA's variable rate to the smelters is based, and the unavailability of energy to serve all of their loads accounted for the declines. Low streamflows also meant reduced sales of \$146 million compared to rate case projections, but these were a \$29 million improvement over 1992.

Total Federal Columbia River Power System operating and net interest expenses rose \$38 million, up less than 2 percent. In 1992, overall expenses had risen \$407 million. As in 1992, weather was the chief problem in 1993. To meet its firm power commitments and to provide adequate flows for fish in a year of low streamflows, BPA had to buy \$222 million worth of power in 1993. Power purchases were 50 percent higher than in 1992, and more than six times what BPA spent on power purchases in 1991.

Southeastern Power Administration

In 1993, the Southeastern Power Administration, with a total of 3,092 megawatts of installed capacity, marketed power from 22 multipurpose projects to 293 power purchasers in 10 southeastern states. Its sale of 8.7 billion kilowatthours (31.3 billion megajoules) of electrical power yielded \$169.3 million in total revenues for 1993. Repayment of Federal investment in 1993 was \$47.8 million. As of the end of 1993, Southeastern had repaid \$435 million of the \$1.4 billion Federal investment. Total cumulative revenue through 1993 was \$2.3 billion, of which \$1.1 billion was for operation and maintenance and \$781 million for interest.

Because Southeastern does not own or operate any transmission facilities, it markets power over the transmission systems of other utilities in the region and compensates them for their services.

Southeastern continues its efforts to negotiate a contract with the Kentucky Utilities Company to transmit federally generated power to preference agencies in its service area. Southeastern completed a public participation process and issued a final power marketing policy during 1993 for the Cumberland System to allow the extension of existing contracts and to enter into contracts with the preference agencies in the Kentucky Utilities area for a term of approximately 20 years upon negotiation of suitable marketing contracts (Figure 7-8).

Work has begun on a new power marketing policy and new contracts for the Georgia-Alabama-South Carolina System of projects. Existing contracts expire in 1994 and 1995.

In May 1988, the United States District Court for the District of South Carolina granted a preliminary injunction against the installation of four reversible pump-generator units at the Richard B. Russell Project, located on the Savannah River between Georgia and South Carolina. The South Carolina Department of Wildlife and Marine Resources, with the National Wildlife Federation, the South Carolina Wildlife Federation, and others, filed suit contending that the pumping process would kill many fish. They further alleged that the U.S. Army Corps of Engi-

7-8. In February 1992, Southeastern, its customers, and the U.S. Army Corps of Engineers formed a new partnership called Team Cumberland in an effort to improve their working relationship. Here, from left to right, Don Norris of the East Kentucky Power Cooperative, Southeastern Administrator Johnny McAllister, and General Albert Genetti of the Corps of Engineers display the Team Cumberland logo, which features the partnership's theme, "Partners Advancing Responsible Hydropower."

neers had failed to comply with provisions of the National Environmental Policy Act, the Fish and Wildlife Conservation Act, and other statutes and regulations. Installation of the reversible pump-generator units would provide 300 megawatts of capacity, for a total project-installed capacity of 600 megawatts.

In January 1989, the U.S. Fourth Circuit Court of Appeals, in *South Carolina Department of Wildlife and Marine Resources v. Marsh*, 866 F2d 97 (4th Cir. 1989), reversed the injunction and ruled that the Corps of Engineers could resume construction and installation of the pump units but could not test or operate the units until further order of the district court. In September 1991, the Corps sought authority to test and operate the pump units by filing a motion to dissolve the preliminary injunction and an administrative record that included a supplemental environmental impact statement. During 1992, the district court entered an order establishing testing procedures and schedules negotiated by the parties. Testing began in July 1992 and continued in 1993. Dredging of the channel below the Richard B. Russell Project is scheduled for 1994. If testing proceeds on schedule, the Corps expects the pump units to be commercially available in 1996.

Unit outages in the Georgia-Alabama-South Carolina System, which caused numerous interruption credits in recent years, were much less prevalent in 1993. Capacity interruption credits Southeastern granted to compensate customers resulted in a loss of approximately \$250,000 in revenues.

In 1992, Southeastern selected the Hinton-White Sulphur Springs-Philippi Power Authority as the non-Federal financial sponsor for the proposed Bluestone Hydropower Project, to be located at the existing Bluestone Dam on the New River in Hinton, West Virginia. As a sponsor for this project, the power authority entered into an agreement with the Corps of Engineers to finance the necessary primary evaluation and feasibility studies.

In 1993, Southeastern and the Corps of Engineers continued their study of the feasibility of an upgrade of the Wolf Creek hydroelectric project. The Corps will seek authorization of the project in the Water Resources Development Act of 1994.

In 1992, the U.S. Fish and Wildlife Service conducted studies of the Alabama sturgeon in an effort to have it listed as an endangered species and to declare the Alabama, Cahaba, and Tombigbee Rivers as critical habitats. A public hearing was held in 1993, and another hearing is scheduled for 1994. Operations at the Robert F. Henry, Millers Ferry, Allatoona, and Carters projects could be adversely impacted.

In cooperation with area generation and transmission organizations, Southeastern conducted workshops for preference customers on integrated resource planning during 1993.

Southwestern Power Administration

The Southwestern Power Administration, headquartered in Tulsa, Oklahoma, markets and distributes hydroelectric power produced at 24 hydro projects constructed and operated by the U.S. Army Corps of Engineers. Southwestern owns and operates 1,380 miles (2,220 kilometers) of high-voltage transmission lines, 24 substations and switching stations, and 46 microwave and very-high-frequency radio sites. Southwestern's Operations (Dispatch) Center is in Springfield, Missouri, with field offices in Gore and Tupelo, Oklahoma, Jonesboro, Arkansas, and Springfield. From these facilities, Southwestern serves its 96 wholesale customers—municipalities, rural electric cooperatives, and Government installations—located in the 6-state region of Arkansas, Kansas, Louisiana, Missouri, Oklahoma, and Texas.

In 1993, Southwestern experienced a record-setting year in both power generation and revenue. Favorable water conditions allowed for a net energy production of 9.3 billion kilowatthours (33.5 billion megajoules) and exceeded both the average annual generation of 5.6 billion kilowatthours (18.7 billion megajoules) and the system's record set in 1985, 8.6 billion kilowatthours (30.1 billion megajoules). Power generation in 1992 was 7.1 billion kilowatthours (25.6 billion megajoules). In 1993, Southwestern collected \$116 million in gross operating revenue. Of this amount, \$45.8 million was applied toward repayment of the Federal investment. As of the end of 1993, \$298 million (30 percent) of the \$1 billion investment had been repaid to the U.S. Treasury from Southwestern's revenue. This is the 12th consecutive year that Southwestern has increased its repayment of the investment in the Southwestern Federal Power System.

Total cumulative operating revenue through 1993 was \$2.0 billion, of which \$688 million was for operations and maintenance, \$520 million was for purchased power, \$536 million was for interest, and \$298 million of repayment of investment in power facilities. Southwestern's power sales have continued to produce income sufficient to meet or exceed the target level for repayment of capital investment in the generation and transmission system.

Water-based recreation, fish and wildlife, and conservation interests continue to be a major competing-uses issue. In 1993, Southwestern continued to participate with

7-9. A Southwestern employee and an Arkansas Game and Fish Commission employee track trout that have been equipped with radio transmitters. Monitoring gauges located intermittently downstream provide information on water temperature and levels of dissolved oxygen.

the Corps of Engineers and state fish and wildlife agencies in studying the effect of low-dissolved-oxygen water releases, principally on trout and other fishes in the tailwaters of several dams (Figure 7-9). Several short-term operating solutions have been successfully tested and have been installed in two hydroelectric projects.

On August 11, 1993, FERC confirmed and approved a 14.7 percent increase in rates through September 30, 1997, for the Sam Rayburn project. The Robert Douglas Willis project is presently under rates that were also confirmed and approved by FERC on a final basis on August 11, 1993; such rates decreased 30.4 percent and are in effect for the period of April 1, 1993, through September 30, 1997.

In 1993, Southwestern began construction of a new, 2-story, 24,000-square-foot (2,160-square-meter) Operations and Maintenance Center in Springfield, Missouri,

which will house a state-of-the-art Supervisory Control and Data Acquisition/Emergency Management System (SCADA/EMS). This new electronic system will significantly improve reliability and control within the Southwestern service area. The building is expected to be completed in late 1994, and the SCADA system will be operational by the summer of 1996.

Southwestern celebrated its 50th anniversary in 1993 with a well-attended customer conference and special ceremonies honoring agency administrators from the past and present. The theme of the celebration, "Partnerships in Power," emphasized the role of customers in Southwestern's success. The anniversary provided opportunities to examine the past, reaffirm the agency's mission, and plan together for the future.

Southwestern's total quality management (TQM) program moved successfully into its fifth year as Quality Improvement Goals were implemented. Management leadership, strategic planning, customer focus, and training and recognition were established as goals. Specific areas identified for improvement were employee empowerment and teamwork, measurement and analysis, and quality and productivity. Southwestern's administrator was recognized by the Department for the agency's TQM accomplishments and was requested to assume a leadership role in guiding the Department's TQM efforts.

Western Area Power Administration

Western Area Power Administration, headquartered in Golden, Colorado, in 1993 marketed and transmitted power from 10,629 megawatts of capacity produced at 54 hydroelectric powerplants and one thermal powerplant. Power sales are approximately 95 percent of regional hydroelectric generation and 15 percent of national.

Power facilities are part of 13 multipurpose water resource projects, which include Western's transmission facilities and the generation facilities owned and operated primarily by the Corps of Engineers, the Bureau of Reclamation, and the International Boundary and Water Commission. Western's service area covers 3.38 million square kilometers (1.3 million square miles). Western sells power to more than 600 wholesale power customers, including municipalities, cooperatives, public utility and irrigation districts, Federal and state agencies, and investor-owned utilities. They, in turn, provide retail electric service to millions of consumers in these 15 central and western states: Arizona, California, Colorado, Iowa, Kansas, Minnesota, Montana, Nebraska, Nevada, New Mexico, North Dakota, South Dakota, Texas, Utah, and Wyoming.

In 1992, Western marketed more than 34 billion kilowatthours (122 million gigajoules) of power, earning gross operating revenues of \$757.7 million. Annual expenses included \$179 million for operations and maintenance, \$132 million in interest, and \$306 million in power purchases.

In 1992, power generation was at an all-time low of 25.4 billion kilowatthours (91.5 million gigajoules), and reservoir storage continued to decline to a record low of 92.6 million acre-feet (114.2 billion cubic meters). Nevertheless, Western met all contractual obligations to customers and repaid \$16 million of the Government's \$5.3 billion investment in power and other facilities. Cumulative operating revenue totaled \$10.6 billion through 1992. Of this, \$6.9 billion was used for operating expenses, \$1.8 billion for interest, and \$2.1 billion for debt repayment.

Western operates an extensive, integrated, and complex high-voltage power transmission system to supply energy to its customers. Using this 16,454-circuit-mile (26,495-circuit-kilometer) Federal transmission system, Western marketed and delivered reliable electric power to much of the western half of the United States. In 1992, Western's system operators managed the network with no major outages or system disturbances. For its responsiveness to minute-by-minute load changes, Western earned, for the fourth year in a row, a place on the North American Electric Reliability Council's Control Performance Honor Roll. Western's 1,480 Federal employees and approximately 1,000 contractors operate and maintain this system from 50 duty stations located throughout the service area.

Staff at headquarters in Golden, Colorado, and 5 area offices (Billings, Montana; Loveland, Colorado; Phoenix, Arizona; Sacramento, California; and Salt Lake City, Utah) manage sales for 11 ratesetting systems. Customer service and system operations also are supported by district office staff in Bismarck, North Dakota; Fort Peck, Montana; Huron, South Dakota; Montrose, Colorado; and an operations office in Watertown, South Dakota.

Other notable accomplishments during 1992 included the following:

1. Marketed reliable hydroelectric power to 612 customers.
2. Operated and maintained 16,454 circuit-miles (26,475 kilometers) of transmission lines, 268 substations, and other complex electrical facilities.
3. Constructed and upgraded 242 miles (387 kilometers) of transmission lines.
4. Continued funding various research studies supporting environmental research data collection in the

Grand Canyon National Park and Glen Canyon National Recreation Area.

5. Protected fish and wildlife and their habitats by managing power operations to provide beneficial flows. (This included 517 million kilowatthours (1.86 gigajoules) in foregone generation to support habitats that encourage reproduction of endangered birds and fishes.)
6. Continued to develop the Energy Planning and Management Program to ensure long-term planning and efficient energy use by Western's customers. (Integrated resource planning for all customers is a cornerstone of this unique and innovative public policy program.)
7. Changed the name of the Conservation and Renewable Energy Program to Energy Services to reflect the program's new emphasis on efforts to encourage integrated resource planning and expand technical assistance to customers. (The technical assistance involved, among other things, 60 workshops, 250 equipment loans, and 300 irrigation pump tests.)
8. Energized the world's first three-phase, thyristor-controlled series capacitor installation at Western's Kayenta Substation in northern Arizona in a joint project with Siemens Energy, Inc.

In 1993, Western marketed 33.4 billion kilowatthours (120 million gigajoules) of power, earning gross operating revenues of \$737.3 million. Annual expenses included \$325 million for operations and maintenance, \$148 million in interest, and \$304 million in power purchases.

In spite of increased rainfall in 1993 across Western's territory, continued low generation combined with high power purchases made the year lackluster in term of revenue. Net generation totaled about 24.8 billion kilowatthours (90 million gigajoules), down 0.6 billion from 1992. Heavy runoff in the Lower Colorado River Basin in the spring, and the Lower Missouri River Basin during the summer, forced cutbacks in releases from upstream hydroelectric dams. About 11.7 billion kilowatthours (42 million gigajoules) of energy was purchased in 1993 to meet firm contractual commitments. Purchases were slightly lower than 1992's record highs.

Total Western system storage as of September 30, 1993, improved greatly at 118 million acre-feet (145,553 million cubic meters)—or 94 percent of normal. This was an increase of about 25 million acre-feet (30,838 million cubic meters) over end-of-1992 storage. In 1993, Western repaid \$25 million of the Government's \$5.6 billion investment. Cumulative gross operating revenue totaled

\$11.3 billion through 1993. Of this, \$4.2 billion was used for operating expenses, \$3 billion for purchase power, \$1.9 billion for interest, and \$2.2 billion for debt repayment.

In 1993, Western worked to change its organizational culture by articulating its core values and leadership principles. In addition, Western surveyed its entire work force to help determine how to become a more people-oriented organization. Western teams have also undertaken numerous quality initiatives. Small and large efforts to serve customers better, cut processing time, and save resources are yielding results at every duty location.

Western established a craft training center during the year. The center, located adjacent to Western's Montrose District Office, will provide state-of-the-art training to ensure that the expertise of craft workers now reaching retirement age will be efficiently passed to younger workers. The center will also serve as the focal point for advanced training, new information, and new technology for Western's journeymen.

Western staff oversaw work on several major construction projects, including the completion of the Phoenix Area Maintenance Complex, which consolidates maintenance, engineering, and administrative areas under one roof. The \$430 million California-Oregon Transmission Project was also energized during 1993. The project included three new 500-kilovolt substations and more than 180 miles (290 kilometers) of new or upgraded transmission lines. This is Western's largest construction project to date. Service began in March.

Another project brought line crews together from all five areas to completely replace insulator strings on the 101-mile (163-kilometer) Bears Ears-Bonanza 345-kilovolt transmission line between Craig, Colorado, and Venal, Utah (Figure 7-10). Nine crews changed 1,520 defective polymer insulators on 432 towers in just 10 days. This was Western's largest combined maintenance effort to date. During the project, crews worked 8,600 hours without a lost-time accident, spending many of those hours climbing and working on transmission towers 60- to 120-feet (18- to 37-meters) high.

Western joined the Environmental Protection Agency's Green Lights program in 1993, becoming one of the first Federal participants. Under the program, building lighting systems are analyzed for energy use and evaluated for retrofitting where significant cost-savings could be gained. Western continued development of the Energy Planning and Management Program, one aspect of which will commit all Western customers to integrated resource planning for future resources. Technical assistance provided through

7-10. A Western crew positions a ladder as it prepares to remove this angled insulator string on the Bears Ears-Bonanza 345-kilovolt transmission line, which runs through western Colorado and eastern Utah.

Western's Energy Services office chiefly involved helping customers learn how to do integrated resource planning.

Western successfully settled a longstanding dispute with the Pacific Gas and Electric Company regarding the project-dependable capacity of the Central Valley Project. More than a \$400 million difference had existed between the two parties' positions regarding the project's project-dependable capacity, and some of the issues had been disputed since 1982. The settlement allows Western to market various products from its system that it could not under the original contract. This will generate more revenue from Central Valley Project power sales. An environmental impact statement process began in 1993 on the post-2004 Central Valley Project marketing plan to prepare for future marketing decisions.

URANIUM ENRICHMENT

During 1992 and 1993, the Department's uranium enrichment enterprise began restructuring as the United States Enrichment Corporation. The mission remains the same—to provide domestic and international uranium enrichment services, meeting foreign and domestic needs for enriched uranium reliably, economically, and safely, and in an environmentally sound manner—with additional mandates from the Energy Policy Act of 1992 to operate on a profitable basis and maximize the value of the corporation.

Official transition from a Government program to a Government-owned corporation occurred on July 1, 1993.

President Clinton appointed a transition manager to exercise all the powers of the Board of Directors. After a quorum of board members is appointed and confirmed, they will designate a Chief Executive Officer and other officers of the corporation. Within 2 years, the corporation is required to prepare a strategic plan for transferring ownership from the Government to private investors.

A 1990 independent financial analysis of the enrichment enterprise by Smith Barney, Harris Upham and Company concluded that operating as a Government program hampered the uranium enrichment enterprise's competitiveness in a number of ways, including subjecting it to the Federal budget process and using it to meet political rather than business agendas. Among the major benefits of the corporation will be additional flexibilities that will improve competitiveness in the international enrichment marketplace.

Additionally, on February 18, 1993, representatives of the Russian Federation and the United States signed a Government-to-Government agreement covering the U.S. purchase, over a 20-year period, of low-enriched uranium to be converted from 950 tons (860 metric tons) of highly enriched uranium from dismantled Russian nuclear weapons. This agreement will be implemented through a purchase contract between the Department and the Ministry of the Russian Federation of Atomic Energy that was initiated on May 15, 1993. The United States Enrichment Corporation will market the converted material for peaceful use as commercial-grade nuclear fuel.

Obtaining this former Russian weapons material is important on several counts. The purchase contributes to nonproliferation efforts while assisting Russia's efforts to improve economically and develop a market economy by infusing hard currency into that country. Side benefits include Russia's commitment to allocate some of these funds to environmental cleanup and improving nuclear powerplant safety. The latter is an area in which the United States hopes to assist and cooperate with Russia.

The acquisition of the Russian material could benefit the United States Enrichment Corporation as well as the uranium and enriched uranium markets. Availability of this quantity of material will increase the corporation's production flexibilities. Moreover, unlike other producers or suppliers, the corporation will have the incentive and the ability to use or sell the uranium and enriched uranium components of the acquired material in ways that do not disrupt the international marketplace or domestic industries.

Gaseous Diffusion Plants

The uranium enrichment enterprise produces enriched uranium in gaseous diffusion plants located in Paducah, Kentucky, and Portsmouth, Ohio. Although built in the 1950s for defense purposes, for more than 20 years these plants also have enriched customer-provided natural uranium for a fee that recovers the cost of the service. During 1992, the plants, with a combined capacity of 19.2 million separative work units per year, operated at a combined power level of approximately 3,092 megawatts and produced 11.8 million separative work units in 1992. (A separative work unit is the measure of the effort expended in separating and concentrating fissionable uranium-235 (U-235) from nonfissionable uranium-238 (U-238).)

Gaseous diffusion separates U-235 and U-238 by exploiting the differences in the weight of the isotopes. Combined with fluorine to produce the gaseous compound uranium hexafluoride, the lighter isotopic compound passes through porous membranes at a slightly higher rate than the heavier isotopic compound. Cycling the uranium hexafluoride through a series of chambers with membranes—a process called cascading—concentrates the U-235, which can then be chemically converted to a form usable as fuel.

Because electricity accounts for approximately 70 percent of production costs at the gaseous diffusion plants, power is a major focus of cost control efforts. During 1992, the enterprise continued to increase its use of low-cost, off-peak, and other nonfirm power—sometimes available at one-half to one-third the cost of firm power. Contracts providing the least expensive baseload firm power currently available have been negotiated with the gaseous diffusion plants' primary power suppliers—Ohio Valley Electric Corporation and Electric Energy, Incorporated.

The United States Enrichment Corporation should have considerable opportunity and incentive to reduce power costs. Gaseous diffusion operations permit additional uranium to be substituted for power, a process referred to as "overfeeding." Overfeeding can produce cost savings when the uranium used is less expensive than the electric power it replaces. The corporation will have the option to reduce its power costs by overfeeding Russian material that it acquires.

In creating the corporation, the Energy Policy Act of 1992 provided for it to lease the Department's operating gaseous diffusion plants for a minimum of 6 years. The corporation took over the operation of the gaseous diffusion plants on July 1, 1993. The Department will retain ownership and will administer the lease.

The Portsmouth gaseous diffusion plant was also used to produce highly enriched uranium for defense purposes. In 1991, the Department decided to take the highly enriched uranium production facility, known as the "top," off line and put it in standby. Later, the decision was made to shut down the top completely. In November 1992, the Department began to withdraw inventory from the cascade, and completed this process in late January 1993, 4 weeks ahead of schedule. The scheduled activities include having the equipment in standby by November 1994, cleaning the high-enriching equipment, making necessary modifications to permit certain facilities to continue being used for low-enrichment operations once the high-enriching units are safely shut down, and preparing instrumentation to monitor the equipment buffering system. Additionally, an action plan for removal of highly enriched uranium from the site is under preparation.

Actions are being taken at the existing gaseous diffusion plants to ensure that safety of operations is maintained and compliance with all applicable environmental laws and regulations is achieved on a schedule consistent with agreements reached with Federal and state agencies. Within 2 years of the establishment of the corporation, the Nuclear Regulatory Commission, in consultation with the Department and the Environmental Protection Agency, is required to establish safety, health, and safeguards standards for the operation of the gaseous diffusion plants by the corporation.

Uranium-Atomic Vapor Laser Isotope Separation

Uranium-Atomic Vapor Laser Isotope Separation (AVLIS) is a state-of-the-art technology that separates isotopes of uranium by utilizing differences in their response to laser stimulation. The process involves melting uranium metal and converting it into an atomic vapor. Laser beams passing through an atomic vapor mixture of U-235 and U-238 leave the U-235 atoms with a net positive charge. An electromagnetic field then deflects the positively charged U-235 ions to a negatively charged collector, where they condense. Unaffected by the laser beams, U-238 atoms pass through this collector to condense on another collector. The condensed materials flow into separate repositories as enriched uranium liquid, which is cast and then stored in solid form. In a production plant, it is converted to either uranium hexafluoride or uranium oxide that can be used by fuel fabricators to prepare fuel pellets for use in reactor core assemblies. The technical efficiency of the

AVLIS, coupled with electricity requirements far lower than those for gaseous diffusion, offer the potential of significantly lower enrichment costs.

A series of plant-scale integrated enrichment demonstrations of the AVLIS technology began in September 1991. This series included five runs, the last of which produced more than 68 pounds (150 kilograms) of product enriched to above 2 percent U-235. This last run, in December 1992, also validated the projections for production plant performance, confirming production cost projections of approximately \$50 per separative work unit.

Conceptual designs and cost estimates for both 3 million and 9 million separative work unit production plants were completed in 1992. The Department's independent cost estimating team has validated these estimates to within 5 percent. During the remainder of 1993, the AVLIS technology program will focus on demonstrating extended lifetimes of the laser and separator systems and value engineering of their subsystems.

Like other uranium enrichment activities, the future direction of the technology depends, in the near term, on decisions made by the United States Enrichment Corporation. Under the Energy Policy Act of 1992, the corporation is required to assess the economic viability of proceeding with the commercialization of AVLIS technology and other alternative technologies. If the corporation determines to proceed with commercialization, it will have the exclusive commercial right to deploy and use any AVLIS technology patents, processes, and technical information owned or controlled by the Government in exchange for a royalty agreement with the Department.

NAVAL PETROLEUM AND OIL SHALE RESERVES

A summary of operations and production at Naval Petroleum Reserves 1, 2, and 3 is presented in Chapter 3 of this report. Revenues at Naval Petroleum Reserves 1, 2, and 3 totaled \$473 million in 1992, and \$440 million in 1993, as shown in Table 7-7.

At Naval Petroleum Reserve No. 1, located near Bakersfield, California, the Government's share of crude oil produced during the year was sold on the open market through competitive bidding. Table 7-8 summarizes Naval Petroleum Reserve No. 1's 1992 and 1993 crude oil sales. Figures 7-11 and 7-12 show typical facilities. In 1992, Naval Petroleum Reserve No. 1 daily crude oil production averaged 69,500 barrels (9,500 metric tons) of oil, of which the Government's share was 54,200 barrels (7,400 metric

Table 7-7—1992 and 1993 Naval Petroleum and Oil Shale Reserves revenues

1992					
Product	NPR-1	NPR-2	NPR-3	NOSR-3	Total
(dollars)					
Crude oil	326,616,795	1,079,460	17,364,144	40,595 ^a	345,100,994
Natural gas	35,203,883	664,600	—	1,206,766	37,075,249
Propane	17,678,715	13,702	173,063	—	17,865,480
Mixed butane	9,887,300	5,246	729,414	—	10,621,960
Isobutane	3,280,460	—	—	—	3,280,460
Gasoline	21,211,609	63,569	—	—	21,275,178
Carbon dioxide	—	—	—	—	0
Subtotal	413,878,762	1,826,577	18,266,621	1,247,361	435,219,321
Other ^b	37,335,395	245,392	304	0	37,581,091
Total	451,214,157	2,071,969	18,266,925	1,247,361	472,800,412
1993					
Product	NPR-1	NPR-2	NPR-3	NOSR-3	Total
(dollars)					
Crude oil	302,257,380	1,829,639	13,473,077	34,317 ^a	317,594,413
Natural gas	33,504,911	626,068	—	3,501,835	37,632,814
Propane	16,860,322	19,898	184,128	—	17,064,348
Mixed butane	7,916,849	7,739	565,955	—	8,490,543
Isobutane	4,030,141	—	—	—	4,030,141
Gasoline	17,514,249	53,588	—	—	17,567,837
Subtotal	382,083,852	2,536,932	14,223,160	3,536,152	402,380,096
Other ^b	37,258,356	78,843	4,262	0	37,341,461
Total	419,342,208	2,615,775	14,227,422	3,536,152	439,721,557

^a Condensate.^b Includes miscellaneous receipts.

tons) of oil per day and which was sold at an average price of \$16.52 per barrel (\$120.58 per metric ton). In 1993, daily crude oil production averaged 65,421 barrels (11,703 metric tons) of oil per day, of which the Government's share was 50,938 barrels (6,979 metric tons) of oil per day and which was sold at an average price of \$16.23 per barrel (\$118.46 per metric ton).

The Naval Petroleum Reserve Production Act of 1976 (10 U.S.C. 7430(b)(2)) placed constraints on the selling price of Naval Petroleum Reserves crude oil. The price had to be at least the higher of the following amounts: 90 percent of the current sales price of comparable petroleum in the same area, or the price of oil being purchased for the Strategic Petroleum Reserve minus the cost of trans-

**Table 7-8—1992–1993 Naval Petroleum Reserve No. 1
crude oil sales**

Contract dates	No. of companies	Quantity delivered, barrels per day (metric tons per day)	Average sale price, dollars per barrel (dollars per metric ton)
October 1, 1991– May 1, 1992 ^a	10	54,835 (7,512)	16.17 (118.03)
May 1, 1992– October 1, 1992 ^b	12	43,770 (5,996)	17.02 ^c (124.23)
October 1, 1992– April 1, 1993 ^b	11	51,411 (7,043)	16.32 ^d (119.12)
April 1, 1993– October 1, 1993 ^b	7	50,669 (6,942)	16.13 ^e (117.74)

^a Original contract period was October 1, 1991, to April 1, 1992; however, the Department of Energy exercised its option to extend each of the contracts until May 1, 1992.

^b The Assistant Secretary for Fossil Energy directed that beginning June 1, 1992, 20,000 barrels per day of 18G Stevens Zone crude oil be shipped to the Strategic Petroleum Reserve. The remaining crude oil available at 18G was prorated among all the other awardees.

^c The Strategic Petroleum Reserve pays the weighted average sale price of commercial purchasers for Stevens Zone crude oil delivered to 18G for the same delivery period. The Strategic Petroleum Reserve paid an average of \$17.85 per barrel (\$130.29 per metric ton).

^d The Strategic Petroleum Reserve paid an average of \$16.57 per barrel (\$120.95 per metric ton).

^e The Strategic Petroleum Reserve paid an average of \$16.54 per barrel (\$120.73 per metric ton).

7-11. The 23S transfer station at Naval Petroleum Reserve No. 1.

7-12. The 10G dehydration and Lease Automatic Custody Transfer unit at Naval Petroleum Reserve No. 1. This is now the sole Shallow Oil Zone shipping station.

porting oil from the Naval Petroleum Reserves to the Strategic Petroleum Reserve. In April and September 1992, some of the bid prices for the Naval Petroleum Reserve oil did not meet the test, and the Department initiated a transfer of Naval Petroleum Reserve crude oil to the Strategic Petroleum Reserve. Starting on June 1, 1992, the Department transferred approximately 20,000 barrels (2,700 metric tons) of Naval Petroleum crude oil per day from California through a network of six commercial pipeline systems to the Sun Terminal in Nederland, Texas, for storage at Big Hill and West Hackberry. Again, in March 1993, some bid prices did not meet the congressionally mandated test, so shipments to the Strategic Petroleum Reserve continued through September 30, 1993. From October 1, 1993, to April 1, 1994, deliveries to the Strategic Petroleum Reserve will not be made since the successful bids for the September 1993 bid opening exceeded the statutory minimum-price test.

Also, natural gas from Naval Petroleum Reserve No. 1 was sold through competitive bidding during contract periods of 4 months each. Prices paid for this gas are not subject to the Natural Gas Policy Act. Table 7-9 summarizes Naval Petroleum Reserve No. 1 natural gas sales during 1992 and 1993. Approximately 17 percent of the Government's share of natural gas from Naval Petroleum Reserve No. 1 is sold; the remainder is either reinjected to maintain reservoir pressures, used in field operations, or lost to shrinkage after removal of the natural gas liquids.

Table 7-10 summarizes the Naval Petroleum Reserve No. 1 liquid product sales for 1992 and 1993.

In 1992, Naval Petroleum Reserve No. 3 crude oil production averaged 2,345 barrels (321 metric tons) per day of oil and was sold at an average price of \$20.21 per barrel (\$147.51 per metric ton). Natural gas liquids were sold competitively to two companies, which purchased an average of 1,791 gallons (6,788 liters) per day of propane at an average price of \$0.26 per gallon (\$0.06 per liter) and an average of 5,823 gallons (22,042 liters) per day of butane and heavier liquids at an average price of \$0.34 per gallon (\$0.08 per liter). In 1993, Naval Petroleum Reserve No. 3 crude oil production averaged 1,988 barrels (272 metric tons) per day of oil, which was sold at an average price of \$18.74 per barrel (\$136.78 per metric ton). Natural gas liquids were sold competitively to two companies, which purchased an average of 1,512 gallons (5,724 liters) per day of propane at an average price of \$0.33 per gallon (\$0.08 per liter) and an average of 4,786 gallons

(18,117 liters) per day of butanes at an average price of \$0.32 per gallon (\$0.08 per liter). During 1992 and 1993, no natural gas sales occurred at Naval Petroleum Reserve No. 3; all the natural gas produced at that field is reinjected to maintain reservoir pressures.

At the Naval Oil Shale Reserves, the sale of natural gas commenced in June 1989, from the first eight communitized wells in the Parachute Field operated by Barrett Resources Corporation. During 1990, the sale of natural gas commenced from wells involving Naval Oil Shale Reserve No. 3 lands and sold under three separate gas sale contracts. During 1991, the sale of natural gas commenced from 10 additional wells involving Naval Oil Shale Reserve lands and sold under two separate gas sales contracts. In 1992, three more wells were drilled and natural gas was sold through three separate contracts. Sales from these contracts averaged 3,014 million British thermal units (3,180 million kilojoules) per day at an average price of \$0.94 per million British thermal units (\$0.89 per million kilojoules). In 1993, four more wells were drilled and natural gas was sold through three separate contracts. Sales from these contracts averaged 3,014 million British thermal units (3,180 million kilojoules) at an average price of \$1.32 per million British thermal units (\$1.25 per million kilojoules). Sales of associated liquids in 1992 totaled 2,325 barrels (224 metric tons) of condensate at an average of \$17.46 per barrel (\$181.49 per metric ton) and 2,044 barrels (197 metric tons) of condensate at an average price of \$16.70 per barrel (\$173.59 per metric ton) in 1993. Total revenues generated were \$1.3 million in 1992, and \$4.0 million in 1993, which were deposited in the Naval Petroleum and Oil Shale Reserves appropriation account at the U.S. Treasury.

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Table 7-9—1992-1993 Naval Petroleum Reserve No. 1 natural gas sales

Contract dates	No. of companies	Quantity delivered, million Btu per day (million kilojoules per day)		Average sale price, dollars per million Btu (dollars per million kilojoules)	
October 1, 1991– December 31, 1991 ^a	3	48,009	(50,652)	2.52	(2.38)
January 1, 1992– April 30, 1992	1	45,015	(47,494)	2.29	(2.17)
May 1, 1992– August 31, 1992	1	51,054	(53,865)	1.40	(1.32)
September 1, 1992– December 31, 1992	3	44,132	(46,562)	1.92	(1.81)
January 1, 1993– April 30, 1993	1	42,217	(44,541)	1.73	(1.63)
May 1, 1993– September 30, 1993	2	51,892	(54,749)	2.13	(2.01)

^aContract began September 1, 1991.**Table 7-10—1992-1993 Naval Petroleum Reserve No. 1 liquid product sales**

Contract dates	No. of companies	Product	Quantity delivered, gallons per day (liters per day)		Average sale price, dollars per gallon (dollars per liter)	
October 1, 1991– September 30, 1992	2	Natural gasoline	120,702	(456,907)	0.48	(0.13)
	1	Propane	123,998	(469,329)	0.39	(0.10)
	3	Butane	87,383	(330,745)	0.31	(0.08)
	2	Isobutane	19,450	(73,626)	0.46	(0.12)
October 1, 1992– September 30, 1993	3	Natural gasoline	119,369	(451,861)	0.40	(0.11)
	2	Propane	114,658	(434,028)	0.40	(0.11)
	4	Butane	81,808	(309,677)	0.27	(0.07)
	2	Isobutane	23,629	(89,445)	0.47	(0.12)

CHAPTER 8

DEFENSE PROGRAMS

OVERVIEW AND INTRODUCTION

Over the past few years, the world has undergone breathtaking changes. These changes include the end of the Cold War and the collapse of the Soviet Union; the potential spread of weapons of mass destruction to conflict-prone Third World regions; the significant reduction in the numbers and types of nuclear weapons; the emphasis on full compliance with environmental laws, regulations, and accepted safety standards in the nuclear weapons complex; and significant budgetary constraints. These changes have opened up opportunities and created challenges rivaling the greatest in our history, with the result that, for the first time since 1945, the United States is not building any nuclear weapons.

Movement toward nuclear nonproliferation rapidly gained ground. In January 1992, the United States cancelled its last remaining warhead in production. Five months later, in June, the United States and Russia agreed to further reduce the size of their strategic stockpiles to a maximum of 3,500 each by the year 2003. In July, the United States announced a landmark commitment ending its production of plutonium and highly enriched uranium. At the same time, the United States offered to provide assistance to Russia and the independent republics for the safe and secure transportation and storage of their nuclear warheads and nuclear materials. In October, the United States Senate ratified the Strategic Arms Reduction Treaty, formally committing the United States to a dramatic reduction of nuclear weapons. Also in October, Congress established new limitations on underground nuclear testing, including a moratorium through July 1993. On July 3, 1993, President Clinton extended this moratorium through September 1994.

With these changes, the emphasis of activities within the Office of Defense Programs shifted away from the production of new weapons but sustained efforts at maintaining the safety and reliability of the enduring stockpile of nuclear weapons; dismantling warheads being returned from the stockpile; improving the conduct of operations within DOE facilities; reconfiguring the weapons complex to meet the projected smaller needs of the future in a more efficient, environmentally sound fashion; transferring dual-benefit technology from the weapons complex to the commercial sector to enhance U.S. competitiveness; and defining the roles and responsibilities of the weapons laboratories to meet the challenges of a changed world in the late 1990s and beyond.

SUPPORTING THE ENDURING STOCKPILE

The primary mission for the Office of Defense Programs continues to be to maintain the safety, reliability, and effectiveness of the weapons remaining in the stockpile. Defense Programs does this by preserving nuclear weapons technology in DOE scientists, engineers, and technicians; retaining key capabilities for manufacturing, research, development, and testing; and conducting a program of stockpile maintenance and surveillance. The maintenance program replaces limited-life components, and other components that no longer meet stringent quality assurance requirements, in stockpiled nuclear weapons to maintain their performance and reliability. The surveillance program includes a systematic quality assurance and reliability testing program that analyzes components and subsystems for safety and operational effectiveness.

Stockpile support efforts became more important as the Nation began to rely more on a smaller, less diverse stockpile. DOE conducts stockpile maintenance and surveillance activities at the Pantex Plant in Amarillo, Texas; the Kansas City Plant in Kansas City, Missouri; the Mound Plant in Miamisburg, Ohio; the Pinellas Plant in Largo, Florida; the Y-12 Plant in Oak Ridge, Tennessee; and the Rocky Flats Plant in Golden, Colorado. The major weapons systems addressed in 1992 included the W88 Trident II warhead, the B61 and B83 bombs, the W79 artillery projectile warhead, and the W76 Trident I warhead. In 1993, DOE continued maintenance and surveillance activities on the W88, the B61, and the B83 warheads. As noted under the section on "Reconfiguring the Weapons Complex," several of the nonnuclear component production sites will be closed and work consolidated at other locations.

The skills of the scientists, engineers, and technicians within these plants are unique and have taken years to develop to their current high level of technical excellence and sophistication. In 1992, Defense Programs initiated the Production Capability Assurance Program to maintain these skills during a time of weapons disassembly and no new production. The principal objectives of the program are to ensure, at reasonable cost, minimum capabilities in the key processes supporting the enduring stockpile; to maintain viable design, development, and production interrelationships among plants and laboratories; to actively pursue efforts to eliminate and reduce the amount of waste generated by DOE operations; to eliminate or significantly reduce workplace hazards; and to support the reconfiguration of the nuclear weapons complex.

The underground nuclear testing program was a historically important adjunct to ensuring the continuing safety and reliability of the stockpile. During 1992, the Department conducted eight tests at the Nevada Test Site. Five of these were sponsored by DOE as part of its mission to maintain the safety and reliability of the enduring stockpile. Two tests were sponsored by the Department of Defense to evaluate the survivability of military and intelligence systems in nuclear environments. One test was sponsored by the United Kingdom.

The enactment of the Energy and Water Development Appropriation Act for Fiscal Year 1993 on October 2, 1992, began a new statutory limitation on future nuclear testing activities. The Act placed a moratorium on nuclear testing retroactive to September 30, 1992, and continuing through July 1, 1993, and limited nuclear testing after that date to no more than 5 tests annually, with a total of only 15 tests through September 30, 1996. The law permits only

tests of nuclear explosive devices in which certain safety features have been installed, but provides an exception for one reliability test per year and one United Kingdom test per year with certain restrictions. No test would be permitted unless set forth in a plan submitted to Congress. A test ban would then be effective after September 30, 1996, unless a foreign state conducts a nuclear test after that date.

On July 3, 1993, President Clinton extended the testing moratorium for one year, through September 1994. At the same time, recognizing the need for a testing capability, he directed the Department to maintain its capability to resume testing.

One factor in the President's decision was his conclusion that the weapons in the Nation's nuclear weapons stockpile are safe and reliable. The basis for this conclusion was a thorough review by the Administration of weapons safety, surety, and reliability. To maintain the stockpile with the same degree of confidence that nuclear testing provided, President Clinton directed the Department of Energy and the Department of Defense to explore ways to maintain confidence in the safety, reliability, and performance of U.S. weapons without nuclear testing. This direction has led to efforts to establish a stockpile stewardship program that uses past nuclear test data extensively in combination with future, nonnuclear test data and aggressive application of computational modeling, experimental facilities, and simulation.

Stockpile Surveillance and Evaluation

Stockpile surveillance and evaluation will ensure the continued quality and reliability of nuclear weapons throughout their stockpile lifetime. These activities include laboratory system testing, joint flight testing, laboratory component testing, retirement testing, and reliability assessment. The Department is forming a plan to enhance stockpile surveillance as part of the overall stockpile stewardship program. These activities include those discussed in the following subsections.

Hydrodynamic Testing

DOE conducts hydrodynamic experiments to characterize key aspects of the prenuclear phase of a weapon's operation; these experiments are therefore important in the stockpile evaluation and materials compatibility programs. Hydrodynamic testing also supports a development

program that is necessary to retain and exercise weapons-design and engineering skills and to examine alternative weapons-design concepts that incorporate such modern safety features as may be needed. Hydronuclear experiments, in which extremely small amounts of nuclear energy are generated, historically have proven to be very useful to evaluate some aspects of nuclear weapons safety, such as one-point safety questions. The President, however, has not authorized the conduct of hydronuclear experiments as a part of the stockpile stewardship program.

One-point safety is a criterion that specifies the allowable probable fission yield for a nuclear device if its high explosive system is detonated at any one point. One-point safety requires that if such a detonation occurs, the probability be no greater than 1 in 1 million of a fission yield greater than 4 lb TNT equivalent.

Weapons Physics Experiments

DOE conducts weapons physics experiments to improve the data it uses to assess and evaluate the stockpile. These experiments use high power laser and pulsed-power facilities to generate the pressures and temperatures needed to address some aspects of both primary and secondary weapons physics.

Military Systems, Radiation Hardness, and Weapons Effects Simulation

The stockpile stewardship program will provide the U.S. with the capability to simulate military systems, radiation hardness, and weapons effects. DOE and the Department of Defense will use these simulations to help ensure that nuclear weapons and their components, nuclear-capable missiles and aircraft, and other military systems are appropriately hardened against adverse radiation environments.

Review and Analysis of Historical Data

DOE's review and analysis of historical data will include researching, cataloging, analyzing, and preserving the design, test, engineering, and manufacturing data for weapons and weapons experiments, as well as developing and maintaining computer-based archives. These activities will help maintain the Nation's scientific and technical knowledge base as scientists and engineers retire from the weapons program.

Numerical Simulation

DOE plans to use advanced computers and new numerical simulation techniques to significantly enhance U.S. numerical simulation capabilities for assessing the behavior of stockpiled weapons and military systems. Part of the numerical simulation program will also complement and unify information obtained from all other elements of the stockpile stewardship plan, provide a readily accessible comprehensive data base, provide essential capabilities for analyzing and countering terrorist nuclear threats, and enable Defense Programs to attract and challenge a high-quality professional staff.

Engineering Design and Development

Current engineering design and development capabilities are focused on assessing and responding to aging effects, modifications in operations and logistics, and changes in military requirements. Enhanced program elements will provide the information required for understanding the design, output and effects issues and solutions unique to nuclear weapons; provide a basis for addressing modifications to stockpiled weapons resulting from changes to logistics or system requirements; and expand current analytical tools to characterize warhead response to a broader set of normal, abnormal, and combined environments.

Chemistry and Materials

The chemistry and materials element of the stockpile stewardship program is designed to characterize both nuclear and nonnuclear material properties, characterize aging studies and material compatibility issues, advance DOE's understanding of the nuclear weapons stockpile, and enhance DOE's ability to assess and maintain it.

Production Capability

The nuclear weapons production complex currently supports the disassembly, modification, and remanufacture of components for the enduring stockpile. Production and laboratory capability assurance programs and weapons complex reconfiguration activities are evaluating changes to this capability; DOE is still defining the nature of the residual complex.

Safeguards

Safeguards are considered essential to ensuring that the Nation has the technical means and knowledge to support

the nuclear deterrent. Under Safeguard C, DOE has maintained its basic capability to resume nuclear test activities that have been prohibited by treaties, should the United States cease to be bound by such treaties. As noted earlier, the President requires the Department to maintain the capability to resume underground testing.

The stockpile stewardship program functionally satisfies the intent of historical safeguards through the modification of Safeguard C to shift its focus from atmospheric testing to retaining the capability to resume underground nuclear testing, should the U.S. cease to be bound by a Comprehensive Test Ban.

Maintaining the Capability To Resume Testing

Under a Comprehensive Test Ban, the Nation may choose to keep a viable, although possibly reduced, infrastructure and staff at the Nevada Test Site, the Department of Energy's nuclear weapons laboratories, and the Defense Nuclear Agency. These facilities are fundamental to retaining the capability to resume nuclear testing if so directed by the President.

Dismantling Warheads

Nuclear weapons reduction initiatives announced during 1992 accelerated the rate of retirement of weapons from the U.S. nuclear arsenal. The Department dismantles these warheads at the Pantex Plant in Amarillo, Texas. Formerly, the Pantex Plant also assembled the high explosives, nuclear components, and nonnuclear components into nuclear weapons. Now, and for the foreseeable future, the operational focus at Pantex will only relate to weapons dismantlement using the storage, handling, and safeguards and security procedures that have been used to safely disassemble nearly 50,000 weapons over the past 40 years.

The weapons are dismantled in specially designed cells and bays under strict supervision and procedures. The high explosives are removed, and the plutonium components (called "pits") are placed in specially designed steel containers that are stored and secured on an interim basis in earth-bermed bunkers at the Pantex Plant. The highly enriched uranium is shipped to the Y-12 Plant at Oak Ridge, Tennessee, for storage. The remaining components and subassemblies are recycled, disposed of onsite, or shipped to other plants in the weapons complex for disposition.

Anticipating the need to store large numbers of plutonium pits at Pantex, the Department is preparing a draft

environmental assessment on increased interim storage (6 to 10 years) for these pits. DOE released the draft document to the State of Texas for review and comment on December 21, 1992. The state and local stakeholders have presented their comments to the Department. DOE will consider these comments when it prepares the final environmental assessment, scheduled to be released in early 1994. A similar process is underway for the interim storage of highly enriched uranium at the Y-12 Plant.

Improving Conduct of Operations

Defense Programs has a goal to operate its facilities with controlled, consistent, and disciplined procedures. Two critical nuclear weapons complex facilities were subject to intense efforts to improve their operation: the Rocky Flats Plant and the Savannah River Site.

Rocky Flats

Since November 1989, DOE has endeavored to improve the maintenance, testing, and operation of the plutonium facilities at the Rocky Flats Plant. The Department had planned to resume plutonium pit production for new nuclear weapons as soon as it completed and verified the required operational improvements. However, after the cancellation of all new nuclear warhead production, the Department began converting the Rocky Flats Plant from nuclear weapons production to environmental cleanup. In 1992, the Department continued preparations to resume operations because some key production facilities that previously supported the defense mission can support the environmental cleanup mission. For example, Building 559 is an analytical laboratory that will be important to environmental cleanup; it resumed limited operations in 1992 under the new conduct of operations procedures. Also, DOE is preparing Building 707 to initiate the thermal stabilization processes that are needed for cleanup activities.

In September 1993, DOE transferred the responsibility for operating Rocky Flats from Defense Programs to the Office of Environmental Restoration and Waste Management.

Savannah River Site

The K Reactor at the Savannah River Site is the Nation's only source of new tritium for nuclear weapons. Tritium is a radioactive gas that boosts the explosive power of a nuclear weapon, but its half-life is short enough that a

weapon will not work as designed unless its tritium is frequently replenished. Since 1989, the Department has tried hard to prepare the K Reactor for restart. It improved the conduct of operations and the maintenance, testing, and operation of critical safety and environmental systems. In 1992, the Department successfully upgraded the reactor systems and completed the Power Ascension Test Program. This program exercised the reactor's critical safety systems and operational procedures that would be activated in an emergency during reactor operation. After completing this effort in July, the reactor was shut down for additional planned safety and environmental upgrades, which include connecting a cooling tower for thermal mitigation. The cooling tower was completed in December 1992 and connections to the reactor were begun.

On March 24, 1993, Secretary O'Leary announced her decision to shut down the K Reactor and place the facility in cold standby, with no provision for restart. The reactor was ordered shut down because there is enough tritium in the inventory, from weapons being returned for dismantlement, to support both the stockpile and a reserve until after the turn of the century. This gives the Department enough time to plan responsibly for an appropriate and cost-effective replacement source of tritium. Such a source is needed to ensure that the Nation can maintain its nuclear deterrent in the latter part of the next decade, a task that will be incorporated into the effort to reconfigure the weapons complex.

RECONFIGURING THE WEAPONS COMPLEX

In light of rapid changes in the world security structure, the Department continues to monitor and evaluate its policy on restructuring the complex and will make changes as necessary.

Nonnuclear Consolidation

Initially, the Reconfiguration Programmatic Environmental Impact Statement (PEIS) was to have included an analysis of the alternatives for consolidating nonnuclear manufacturing activities at a single government site. This consolidation was a preferred option of the reconfiguration study. The September 1991 disarmament initiative provided an opportunity to accelerate the consolidation of these activities without affecting national security or preju-

dicing alternatives for future decisions on the nuclear work of the weapons complex. The significantly reduced nonnuclear workload made the potential benefits of consolidation even more apparent. In December 1991, the Department proposed that consolidation of the weapons complex be accelerated by preparing a separate environmental assessment of nonnuclear consolidation while continuing to analyze the nuclear elements in the PEIS.

Under the preferred alternative analyzed in the environmental assessment, DOE would consolidate most nonnuclear manufacturing activities at the Kansas City Plant. DOE would preserve certain selected technologies at the weapons laboratories, during the upcoming period of little or no production, and consolidate tritium work at Savannah River, where most tritium work is currently performed. DOE distributed the environmental assessment of the proposed nonnuclear consolidation to affected states and Indian tribes for comment in December 1992.

In response to concerns expressed by members of Congress, the Department prepared two additional studies of nonnuclear consolidation. Released in December 1992, the *Two-Site Nonnuclear Consolidation Study* evaluated the consolidation of nonnuclear manufacturing activities at any two of the current dedicated nonnuclear plants: Mound, Kansas City, or Pinellas. The study concluded that the single-site option for consolidation is the best way to protect the capability of the complex while achieving maximum savings in annual operating costs. The *Tritium Consolidation Comparison Study* assessed the comparative costs and radiological risks of consolidating tritium maintenance, processing, and storage activities at the Mound Plant or the Savannah River Site. The cost report concluded that the life-cycle costs of consolidating tritium activities at the Mount Plant would be nearly \$2 billion greater than consolidation at Savannah River. The comparative risk report concluded that the radiological risk to populations at either site is acceptable.

Responding to congressional requirements, in January 1993 the Department released the *Nonnuclear Reconfiguration Cost Effectiveness Study*, thus certifying that nonnuclear consolidation was cost-effective. Responding to concerns from Members of Congress, on March 9, 1993, Secretary O'Leary appointed three independent consultants to review the certification: Dr. John S. Foster, Jr.; retired Admiral Kenneth L. Woodfin; and Dr. Terry R. Lash. After reviewing the Department's records and documentation and holding hearings in the vicinity of all of the affected sites to take testimony from elected officials and the public, these consultants affirmed the Department's certification. Shortly thereafter, on September 8, 1993, a finding of no significant impact was

approved and the Department began consolidation activities. With this approval, DOE will eliminate the defense mission at the Rocky Flats, Mound, and Pinellas Plants and will make the Kansas City Plant the single, dedicated plant for most of the remaining nonnuclear work of the weapons complex by 1995.

To ensure a smooth transition that maximizes the savings from consolidation, the Department will assist affected workers and communities in order to mitigate the adverse effects of this downsizing. DOE will develop an economic conversion process that will include funding for local community economic planning that will allow communities to identify alternatives to defense activities; planning for potential facility reuse and worker retraining to assist in the transition; and providing seed money for the sites to develop new ventures that would provide alternative missions for the facilities and meet the standards of the Technology Reinvestment Project created by Congress last year.

In announcing her decision to proceed with nonnuclear consolidation, Secretary O'Leary pledged an additional \$15 million in economic assistance to the communities affected by the proposed consolidation. DOE will allocate \$1.5 million to assist in developing worker retraining and potential facility reuse plans at affected facilities. An additional \$1.5 million will be set aside for economic development planning; \$3 will be contributed for every \$1 a community provides. The Department will also provide up to \$12 million for these communities to use in matching funds for defense conversion projects to meet the objectives of the Technology Reinvestment Project. Finally, the Department will facilitate the conversion of these facilities to nondefense uses by leaving equipment in place, unless replacement cost is significantly more expensive.

Nuclear Reconfiguration

Reconfiguring the nuclear portion of the weapons complex for the 21st century also was greatly affected by changing world events. The combined effect of these changes, together with the budget constraints that were already affecting weapons complex activities, caused the Department, in late 1992, to fundamentally reevaluate the course of reconfiguration planning.

On July 23, 1993, the Department announced a Revised Notice of Intent to prepare a programmatic environmental impact statement for reconfiguring the weapons complex. The announcement included the following key revisions:

1. Adding consolidated long-term storage facilities for plutonium and highly enriched uranium; these facilities will or may be needed in the future to fulfill national security requirements
2. Adding the consolidation of functions involving like materials, including the option to integrate certain research, development, and testing functions with the storage and processing functions
3. Deleting the Hanford Site in Washington and adding the Nevada Test Site in Nevada as potential sites for future weapons complex facilities
4. Changing the no-action alternative as a result of mission changes at weapons complex sites, including the transfer of Rocky Flats to a clean up mission and placing the K Reactor at Savannah River in cold standby

These proposed changes reflect the fact that the future nuclear weapons complex can be even smaller and more integrated than envisioned in the original Notice of Intent. They also reflect the increased importance associated with stewardship of existing special nuclear materials that will or may be used to meet future national security requirements.

Subsequent to its release, the Department began a series of public hearings on the Revised Notice of Intent. Beginning in early September and running through the middle of October 1993, the Department provided an opportunity for state and local governments and stakeholders at all of the sites affected by the Revised Notice to provide comments.

The draft programmatic environmental impact statement is expected to be released in 1994 for public comment. The statement will analyze alternatives for configuration of the complex and compare them to the effects of not reconfiguring the complex. Expected to be completed in 1994, the programmatic environmental impact statement will form the basis for a Record of Decision on the configuration of the future weapons complex. The Department will then prepare a Reconfiguration Plan based on the Record of Decision that will provide specific direction implementing the Decision. At that time, project specific National Environmental Policy Act documents would be prepared.

DEFINING ROLES AND RESPONSIBILITIES OF THE DEFENSE LABORATORIES

The testing and production sites were not the only elements of the complex that were affected by the dramatic changes in the international political environment, the declining number of nuclear weapons, and the imposition of an underground nuclear testing ban. Also affected were the defense laboratories: Lawrence Livermore National Laboratory, Los Alamos National Laboratory, and Sandia National Laboratories. Key national assets, these facilities were originally chartered with a nuclear weapons mission. They played, and continue to play, a critical role in maintaining the stockpile by providing the research, development, and testing capabilities that ensure the safety and reliability of the Nation's nuclear arsenal. That mission remains a key driver for the three defense laboratories, even in consideration of the world changes in 1992.

Among the changes at the laboratories was a change in contractor management at Sandia. After 40 years of service to the Nation as management and operating contractor, AT&T decided that the Sandia efforts no longer fit into its corporate mission. After a careful review of proposals to manage Sandia, the Department selected Martin Marietta to take over on October 1, 1993.

Ironically, it is the success of these laboratories in their principal mission that has brought about a need to redefine their roles and responsibilities in the post-cold-war era. As the defense mission declines in relative importance at these laboratories, the Department must determine how best to maintain their core competencies, that is, the capabilities that support the enduring nuclear weapons stockpile and prevent technological surprise. Scientific and technical competence will ensure the U.S. ability to design and test new weapons systems if they are needed, provide the rigorous technological base needed for enhanced nonproliferation and arms control activities, and provide the wellspring from which new technological initiatives for commercialization may arise. At the same time the Department must also determine how best to focus laboratory efforts to meet new and emerging national needs. At the close of 1993, the Department began to define and build a consensus on the proper focus and the future roles and responsibilities for these laboratories in meeting the challenges of the 1990s and beyond. This complex, multifaceted effort continued into 1994.

Many of the fields necessary to support core competencies also have civilian applications, and, over time, the

weapons laboratories have responded to other national needs and evolved into multiprogram laboratories. They have a wealth of technologies, facilities, and expertise for advances in computer and computational sciences, material sciences, physics, chemistry, and systems engineering and production processes, among others. Leveraging these "dual-benefit" technologies allows the laboratories to maintain their core competencies as state of the art and to contribute to the economic and competitive success of U.S. industries in the world market.

These dual-benefit use technologies are transferred to the private sector in a variety of ways including data and information exchanges, cooperative agreements, cost-shared procurements, licensing agreements, personnel exchanges, technical assistance agreements, user facilities agreements, and work-for-others agreements.

The cooperative research and development agreement (CRADA), established by the National Competitiveness Technology Transfer Act of 1989, is a rapidly growing tool of the laboratories in their efforts to meet their expanding roles. Under a CRADA, government and industry agree to share technology benefits as well as the funding burden. By September 30, 1993, Defense Programs, along with the three weapons laboratories, had executed 172 CRADAs valued at \$555 million. The Government's share was approximately 55 percent, or \$249 million; private industry contributed the remainder. Companies involved in these CRADAs included General Electric, Motorola, Dow Corning, and Signetics. The ongoing efforts span research and development in high-performance computing, high-definition television, flat-panel displays, electronics, information highways, and in manufacturing, waste minimization, and environmental cleanup technologies, among many others.

For example, all three weapons laboratories and a host of industrial partners are developing advanced x-ray projection lithography technology to help the U.S. regain the lead in the integrated circuit production market. Lawrence Livermore National Laboratory and Industrial Tools Inc., have developed an improved machining system that can slice materials such as ceramics, carbides, glass, and plastic twice as accurately as before. This technology will allow more accurate manufacturing of disk-drive heads and silicon wafers, among other applications. Additionally, all three labs, the Y-12 Plant, and the automobile industry are cooperating to develop lightweight materials for automotive applications.

SUMMARY

1992 and 1993 were years of significant change and redirection for the Office of Defense Programs. The end of Cold War and the collapse of the Soviet Union requires a profound change to the nature of the Department of Energy's nuclear weapons complex and a strengthening of the Department's national security activities supporting U.S. and international nuclear counterproliferation activities. Responding with programs that build upon and enhance the strengths of the DOE complex and national laboratories, emphasizing commitments to environment, safety, and health, and achieving these objectives within constrained budgets is the challenge facing Defense Programs in the future.

NAVAL REACTORS

Naval Reactors is responsible for providing the Navy with effective nuclear propulsion plants and ensuring their safe and reliable operation. Maintaining the viability of the operating fleet while protecting the public and the environment is the program's first priority. This effort involves the design, development, testing, evaluation, and continued improvement of nuclear propulsion plants. Much of the technology for the civilian nuclear energy industry has come from this program. In fact, some of the technology developed in this program is directly applicable to, and

an inherent part of, DOE's nuclear fission energy program. Consequently, the program is placed organizationally under the Office of Nuclear Energy.

More than 40 percent of the Navy's combatants rely on nuclear power to accomplish their missions, including strategic deterrence. These ships can operate indefinitely at high speed, unhindered by the need to refuel—reducing their vulnerability and providing the capacity for sustained combat operations. The objective of the Naval Reactors development effort is to design and develop Naval reactors with increased performance, to ensure continued safety and reliability, and to simplify operating and maintenance requirements.

In the areas of plant development, reactor development, and reactor operation and evaluation, Naval Reactors continued to investigate materials behavior, thermal-hydraulics, nuclear physics, heat transfer, design analysis methods, and manufacturing and chemical processes. The office operated land-based prototype propulsion plants used for long-term testing of reactor cores, components, materials, and systems. These efforts continued to provide the basis for nuclear propulsion development at all stages, including the support of the operating fleet and new reactor plants for the Navy's Seawolf Class submarines and the new attack submarine.

During 1992 and 1993, the sixth Nimitz Class aircraft carrier, George Washington, 2 Trident submarines, and 4 Los Angeles Class attack submarines were delivered. Construction continued on 2 aircraft carriers, 5 Trident missile submarines, 11 Los Angeles Class attack submarines, and 2 Seawolf Class attack submarines.

CHAPTER 9

NONPROLIFERATION AND NATIONAL SECURITY

INTRODUCTION

In 1993, the Department of Energy began to restructure its national security programs as part of its transition to a post-cold war world. The restructuring consolidates these activities—intelligence, arms control and nonproliferation, security, and emergency response—under a single office, the Office of Nonproliferation and National Security (formerly the Office of Intelligence and National Security). This new office also controls the research and development programs related to DOE's national security activities. By consolidating these functional areas into a single entity, and thus better integrating its national security expertise, the Department can respond more effectively to the dangers posed by the spread of nuclear weapons, other weapons of mass destruction, and the means to use them.

Additionally, this consolidation supports the Secretary's desire, as a part of the Clinton Administration's effort in reinventing government, to improve the managerial effectiveness of the Department by reducing the number of organizations required to report routine activities directly to the Secretarial level.

Intelligence and related activities are conducted by four elements: Foreign Intelligence, Counterintelligence, Threat Assessment, and Intelligence Support and Security. Foreign Intelligence provides policy-makers and the intelligence community with information on nuclear weapons proliferation; nuclear weapons security; fossil, nuclear, and renewable energy supplies; foreign science and technology; energy economics; and energy-related environmental issues. Counterintelligence identifies and helps to neutralize foreign intelligence attempts to acquire classified or sensitive unclassified DOE information, acting in

coordination with the Federal Bureau of Investigation and the Central Intelligence Agency. Threat Assessment conducts analyses of actual or potential foreign or domestic threats to Department facilities and activities. Threat Assessment also provides technical evaluations and operational support to other U.S. Government agencies concerned with threats involving nuclear materials and facilities. Finally, Intelligence Support and Security coordinates DOE's foreign intelligence information requirements.

Arms Control and Nonproliferation uses the Department's unique technical and analytical resources to support the Administration's arms control and nonproliferation objectives. This area includes four major components: arms control, nonproliferation policy, export control, and international safeguards. The Arms Control program provides policy and technical analysis; assists with treaty negotiations, implementation, and compliance determinations; and assists the nuclear weapons states of the former Soviet Union with issues concerning the dismantlement of nuclear warheads. The Nonproliferation Policy program oversees support for the International Atomic Energy Agency; assists U.S. regional nonproliferation efforts; analyzes global proliferation trends; and sponsors efforts to reduce the worldwide use of highly enriched uranium. Under the Export Control program, the Office participates in the development and implementation of controls on U.S. nuclear, nuclear-related, and dual-use items, and provides technical and policy support for international export control regimes, such as the Nuclear Suppliers Group and the Coordinating Committee on Multilateral Export Controls. Finally, the International Safeguards program provides technical and policy support for international safeguards regimes including the

International Atomic Energy Agency and regional agreements.

Security Affairs manages the Department's comprehensive safeguards and security program. It also defines policy and procedures for classifying and declassifying information. Beginning in 1993, Security Affairs will lead a major declassification effort in concert with the Vice President's National Performance Review. Additionally, Security Affairs directs the development program that provides state-of-the-art technologies for more effective and cost-efficient security throughout the Department. Security Affairs also manages the Department's security clearance program, and is working to reduce the number of clearances required throughout DOE facilities.

Emergency Management serves as the Department's focal point and interagency point of contact for emergency preparedness and response activities. Its main goal is to ensure that DOE's responses to all emergencies are integrated and coordinated. Its programs encompass planning, development, readiness assurance, and testing of the Department's emergency response capabilities; it ensures that DOE can respond to events ranging from widespread fuel supply disruptions or power outages to a large-scale hazardous material or radiological emergency.

Research and Development activities provide the Department with the appropriate technological tools to assist in verifying arms control treaties; collecting and processing technical intelligence; detecting the proliferation of weapons of mass destruction; maintaining national and international safeguards and security; and conducting counterintelligence, counterterrorism, drug interdiction, environmental, and other activities that affect national security.

Combining these programs under the direction of the Office of Nonproliferation and National Security has enabled the Department to reduce duplication of effort and to manage its national security programs more effectively.

RESEARCH AND DEVELOPMENT

Role and Mission

The Research and Development element directs the research program to develop advanced detection technologies and analysis tools to support proliferation detection and arms control treaty verification. The program supports the requirements of the U.S. Government and appropriate international agencies through its research and development activities at the DOE national laboratories, which

range from fundamental research on sensor materials and novel detection schemes to developing, testing, and demonstrating advanced prototype detection systems. The program also supports commercializing developed technologies, timely technology transfer to end users, and dual-use and spinoff applications.

The technologies developed under the Detection Technology program primarily support requirements to monitor and verify compliance with arms control agreements involving nuclear weapons and is developing systems to detect, identify, locate, and characterize the signatures of clandestine weapons development programs.

Onsite Systems Office

The Onsite Systems Office sponsors basic research on detectors of radiation and chemical warfare agents and on the development of advanced multiuse devices. These are used for treaty verification, proliferation detection, and in support of U.S. policies, initiatives, and unilateral declarations that are referred to as transparency and confidence building measures. These technologies are generally man-portable (preferably handheld), feature real-time analysis and data presentation, and are to be used for intrusive onsite inspections.

Warhead Dismantlement and Special Nuclear Material Control Program

The Warhead Dismantlement and Special Nuclear Material program supports the U.S. arms control policy community and international organizations that seek to monitor or to prevent nuclear weapons proliferation. The program also applies the state of the art in fissile material accountability to support bilateral U.S.-Russian negotiations on safeguards and material control and accountability.

The program develops detection, measurement, and analytical techniques that are used to validate treaty-mandated and unilateral declarations about the status and disposition of nuclear weapons and special nuclear materials. The program develops ways to use the signatures of nuclear weapons and their components without revealing classified information. The program develops advanced technical means to verify accountability and the chain of custody of special nuclear material and nuclear weapons. It includes developing data authentication for plant process monitors, conducting vulnerability assessments on commercially available special nuclear material assay technology, and developing advanced seals and tags. The pro-

gram goal is to ensure high confidence in data obtained from sensors and monitoring systems operating in a treaty or cooperative environment and to document known or suspected vulnerabilities.

The Warhead Dismantlement and Special Nuclear Material Control Program accomplished the following in 1992 and 1993:

1. Demonstrated advanced tag and seal technologies to U.S. and Russian negotiators working on the agreement between the United States and the Russian Federation concerning the disposition of highly enriched uranium resulting from dismantlement of nuclear weapons in Russia.
2. Demonstrated to the Department of State DOE's current capability to track and verify the location of treaty-limited items using commercial satellite technology
3. Prepared a report to Congress, *Verification of Nuclear Warhead Dismantlement and Special Nuclear Materials Controls*
4. Conducted a test and evaluation measurement program at the Oak Ridge Y-12 plant, to support the ongoing U.S. dismantlement program
5. Completed vulnerability assessments on three widely used safeguards technologies

Cooperative Monitoring Program

The Cooperative Monitoring technology development program supports U.S. government initiatives, treaties, and agreements for the international control of weapons of mass destruction. These systems are prototypes of field-deployable sensors and unattended multisensor technologies that demonstrate U.S. capability to augment onsite inspections or national level declarations. DOE initiated this new program pursuant to the Weapons of Mass Destruction Control Act of 1992.

Radiation Detection Technologies Program

The Radiation Detection Technologies program is a core technology development program that advances the knowledge of candidate radiation detection materials. The program also develops prototype systems to demonstrate new concepts and advances in electronics and computer software to improve data collection and interpretation. The program develops portable nuclear high-resolution gamma-ray spectroscopy, handheld low-resolution gamma and neutron detector technologies, handheld mass and optical spectrometers, and field instruments that determine ura-

nium and plutonium isotopes. A major accomplishment has been the development of a system that can distinguish between nuclear and nonnuclear systems when inspecting air launched cruise missiles under the protocols of the Strategic Arms Reduction Treaty.

Onsite Geophysical Measurements Program

The Onsite Geophysical Measurements program develops a technology base necessary to characterize the close-coupling seismic mechanisms that distinguish underground nuclear explosions from earthquakes, mining explosions, and other seismic sources. This program develops cost-effective fieldable instrumentation for onsite measurements under a comprehensive test ban treaty. The objective of the seismic effort is to understand the close-in phenomenology between shock waves and geology to support the development of new discriminants for improved assessment of treaty compliance.

A current example of this work, the Nonproliferation Experiment, was conducted in September 1993, when 2.9 million pounds of commercial blasting agent was detonated at the Nevada Test Site. This experiment provided critical data for developing the analytical techniques to distinguish between seismic signals generated by nuclear explosions and those generated by chemical explosions, when those explosions have the same energy and are conducted in the same geologic media. The data may also be used to design meaningful calibration procedures for seismic verification in all regions of the globe. The results from such an experiment will be very important to developing verification procedures for a comprehensive nuclear test ban.

Chemical Weapons Detection Program

The Chemical Weapons Detection program develops and demonstrates methods and systems to nondestructively detect and verify declared or suspected chemical weapons and their production facilities. These technologies support the Wyoming Memorandum of Understanding (a bilateral agreement with Russia) and the Chemical Weapons Convention. Two chemical weapons nondestructive evaluation technologies were included on the U.S. Equipment List for the U.S.-Russian Bilateral Inspection. These technologies are being considered for joint use by the U.S. and Russia and demonstrated in Moscow in November 1993. The two technologies include the highly successful Portable Isotopic Neutron Spectroscopy system and the Small Ultrasonic Detection System. The neutron spectroscopy system was and continues to be used to support the

U.S. Army Technical Escort Group in identifying buried munitions uncovered at current and former Department of Defense sites, such as on the American University campus in Northwest Washington, D.C. The Office of Research and Development is transferring to U.S. industry a portable gas chromatograph/mass spectrometer that was developed for treaty verification.

Regional Monitoring Systems Office

The Regional Monitoring Systems Office programs focus on using effluent and geophysical measurements to detect, identify, locate, and characterize the proliferation of nuclear weapons and other weapons of mass destruction. The detection technology research is primarily focused on the suspect site scenario: Chemical effluents or seismic data are used to fingerprint production or testing activities as evidence of the existence of a proliferant's weapons program.

Effluent Detection and Analysis Program

The Effluent Detection and Analysis program develops ways to detect chemical signatures from proliferation activities. Projects include a major compilation of signatures including chemical species and concentrations. The program has also developed ultra-trace sensitivity to levels approaching parts-per-quadrillion. The program is also improving selectivity, such as the ability to detect trace levels of chemical weapons materials in the presence of pesticides or the ability to accurately measure a molecular fragment of a specific mass. Other technologies include remote sensors that use various spectroscopic techniques, such as infrared absorption, millimeter wave emission, and laser-induced fluorescence, to detect chemical species that are associated with nuclear weapon production.

The program's key accomplishments for 1992 and 1993 include the following:

1. Compiling a comprehensive study of nuclear proliferation signatures
2. Developing an instrument that detects the presence of trace quantities (sub-monolayer) of low-volatility chemical weapons materials on various surfaces

(for example, leaves, paint chips, gaskets, and so forth)

3. Detection of several isotopes (^{129}I , ^{36}Cl , ^{14}C) at concentration levels approaching parts-per-quadrillion using accelerator mass spectrometry
4. Developing ion-trap mass spectrometry to achieve high sensitivity (parts per trillion) in the analysis of many different species for a wide range of samples

Airborne Multisensor Pod System Program

The Airborne Multisensor Pod System program collects imaging and nonimaging data for multisensor data research and sensor development. One pod contains a highly sophisticated digital synthetic-aperture radar; another contains a variety of photographic and digital-imaging sensors. The program has constructed the first two pods and is testing them for flight certification. The program has completed sensor selection for a third pod, which will identify and monitor airborne effluents and is well along with its design. Representatives of various U.S. Government agencies involved in nonproliferation activities were briefed and invited to a static display of the Airborne Multisensor Pod System hardware at Andrews Air Force Base on September 8 and 9, 1993.

Chemical Analysis by Laser Interrogation of Proliferant Effluents Program

The Chemical Analysis by Laser Interrogation of Proliferant Effluents program's goal is to develop and demonstrate laser-based systems for remotely detecting and characterizing chemical effluents from nuclear proliferation activities. This program will emphasize long-range (remote) detection and technology development, concentrating on signal processing and laser detection. The program was initiated in May 1993 with multinational laboratory participation. The participating national laboratories have agreed on the comprehensive program plan, a proposed schedule, and a test plan. The laboratories have minimized overlapping activities and will share data cooperatively.

Regional Geophysical Measurements Program

The Regional Geophysical Measurements program develops and tests nonseismic instrument and data analysis systems to enable the Government to effectively verify the Treaty on the Non-Proliferation of Nuclear Weapons and a future Comprehensive Test Ban Treaty, and other bilat-

eral or multilateral agreements on nuclear testing. The program objective is to foster, develop, and evaluate the technology and concepts necessary to detect and identify nuclear detonations that might occur underground, at sea, or under cloud cover, and to distinguish these tests from earthquakes and nonnuclear explosions.

The program's key accomplishments for 1992 and 1993 include the following:

1. Conducted a workshop for nuclear explosion detection experts from across the U.S. Government, industry, and academia; the workshop identified the key problems for discriminating nuclear explosions underground, in the sea, and in the air
2. Examined the potential for an infrasonic discriminant between earthquakes and underground nuclear tests, using an existing DOE-developed data base of atmospheric infrasonic signals
3. Demonstrated a technique for discriminating quarry blasts from underground nuclear tests, using shock-waves generated by ground motion and coupled into the air
4. Initiated a pilot study to determine the feasibility of using existing over-the-horizon radar systems for detecting buried structures
5. Developed an advanced underwater acoustic array for use in conjunction with the existing Navy system for discriminating earthquakes from nuclear explosions

Seismic Verification Research and Development Program

The technology base provided by the Seismic Verification Research and Development program enables DOE to rapidly deploy systems for high-confidence wideband seismic data acquisition, as monitoring needs arise. This program consists of a core project with several complementary projects that address specific applications. The general approach is to assess monitoring requirements; assess the capabilities of existing techniques; study the phenomena and instrument technology related to seismic verification in order to understand how source region effects on verification signals can affect monitoring capabilities; and conduct a multidisciplinary integrated analysis of ground motion, seismic, atmospheric, and geologic data in order to improve DOE's understanding of explosion source phenomenology. This program supports current and future nuclear testing treaties, for example, the Comprehensive Test Ban Treaty.

Remote Sensing Systems Office

The Remote Sensing Systems Office develops and implements satellite-based instrumentation for detecting, identifying, locating, and characterizing nuclear explosions, and for detecting clandestine activities that may lead to the proliferation of weapons of mass destruction.

Nuclear Explosion Detection Program

The Nuclear Explosion Detection program supports design, development, fabrication, and operation of the satellite-based nuclear explosion monitoring sensors that are needed to monitor the atmosphere and near-Earth space for nuclear explosions. The program has three primary objectives: verification of the Limited Test Ban Treaty, verification of the Nuclear Non-Proliferation Treaty, and strategic battle management in the event of war. (The U.S. Air Force funds this third objective.) Operational systems currently provide continuous worldwide surveillance from the Global Positioning System and other military platforms. The United States has launched more than 90 satellites or space probe payloads during the 34 years of this program.

Proliferation Detection Program

The satellite-based Proliferation Detection program is an advanced technology development program. Its goal is to prove and demonstrate new ways to remotely detect nuclear proliferation activities before a device is detonated, as well as to remotely detect other clandestine military activities. The program additionally serves as a test-bed for intelligence- and environment-related multiple-user sensor systems.

The program's major accomplishments during 1992 and 1993 include delivery of 4 operational payloads to integrating contractors; the support of 12 operational launches; and the launch and initial experimental operation of the Array of Low Energy X-Ray Imaging Sensors (ALEXIS), a low-Earth-orbit satellite that is the Department of Energy's first wholly owned small research satellite.

Advanced Systems Office

The Advanced Systems Office develops new ideas and technologies that could extend U.S. capabilities for treaty verification and proliferation detection. These activities

are often high-risk, proof-of-concept efforts that provide a basis for future projects in the other three research areas. An example is the Multisensor Data Research program, which develops advanced computer processing methods for converting massive amounts of data into information in a timely manner. To exploit the synergism that can result from multisensor data collection, projects in the Multisensor Data Research program explore multiple methods of data fusion by using neural networks, expert systems, target recognition, feature extraction, and maximum likelihood estimators.

INTELLIGENCE ACTIVITIES

Introduction

Both legislative and executive direction mandate the Department of Energy's intelligence roles and responsibilities in support of the national defense. DOE senior intelligence managers and staff actively participate in a number of interagency intelligence panels, policy groups, boards, and programmatic working task forces. DOE provides expert intelligence resources and personnel to other agencies in order to improve interagency communications, coordination, and program management.

Under provision of Executive Order 12333, DOE's intelligence program resources fulfill the following three-fold mission:

1. Producing and disseminating the foreign intelligence necessary to carry out the Secretary's responsibilities
2. Participating in setting the requirements for national intelligence collection and analysis in areas of the Department's special expertise
3. Providing expert technical, analytical, and research capabilities to other intelligence agencies

Ongoing and Future Initiatives

The Department's intelligence activities encompass a number of timely and internationally sensitive subjects that include nuclear technology and materials; the proliferation of weapons of mass destruction; arms reduction; worldwide science and technology capabilities and intentions; energy-related factors affecting world commerce, econom-

ics, and competition; and military, economic, and political events that are related to the Department's programmatic areas of responsibility. DOE also provides intelligence and technical support to national law enforcement efforts to counter espionage and physical threats, both foreign and domestic, against DOE facilities, programs, and personnel. The Department is authorized to carry out specific domestic intelligence-related activities in the areas of counterintelligence and terrorist threat assessment. DOE effectively uses the resources found in its eight field intelligence elements, national laboratories, and departmental organizations to establish and implement DOE intelligence requirements; to facilitate authorized access to intelligence information; to represent DOE's interest in appropriate intelligence community forums; and to arrange other intelligence support that may be required to accomplish the Department's policy objectives.

Foreign Intelligence

The Department's intelligence analysts analyze foreign intelligence on subjects relevant to DOE responsibilities on issues of global nuclear energy; proliferation intelligence; energy, economic, and trade intelligence; arms control monitoring; the nuclear weapons and military-related science and technology efforts of the declared nuclear-weapon states; and energy emergency policy, planning, and crisis management. This ensures that senior DOE officials and policy-makers receive current intelligence reports.

During 1992 and 1993, DOE continued to play a major role in analyzing the threat to global stability and to United States interests posed by the successor states to the Soviet Union, whose political fragility and declining military cohesion have dramatically weakened their centralized control over nuclear weapons. Because the opening of the former Soviet bloc has also contributed to a dramatic increase in the worldwide availability of nuclear materials, DOE established a new program to analyze the production and availability of such materials to potential proliferant countries. Intelligence's new science and technology program focuses on foreign commercial and military research in areas critical to United States military and commercial competitiveness.

In late 1992, DOE initiated the Defense Nuclear Materials Intelligence Analysis Program in response to concerns about the increasing amount of weapons-grade nuclear materials in the world. This program allows DOE to better track and understand international defense nuclear

materials production and availability. In addition, DOE is also analyzing the increase in world stocks of such materials that will occur as nuclear weapons are decommissioned after the turn of the century.

DOE intensified its intelligence analysis of the impact of Russia's political and economic deterioration on the safety, security, and control of the former Soviet Union's nuclear stockpile. DOE has also been developing a broader understanding of Russian strategic nuclear command- and-control procedures, nuclear forces operations, and technical capabilities with regard to weapons security and use-control. DOE is also undertaking studies to clarify nuclear warhead maintenance requirements and operational safety conditions and practices in the successor republics.

Counterintelligence

DOE, as a member of the U.S. intelligence community, is responsible for identifying and neutralizing the foreign intelligence threat to classified DOE programs and activities and for ensuring counterintelligence awareness at all levels of the Department.

The very nature of the Department underscores the importance of this program. The volume of sensitive information possessed by DOE and its contractor personnel and the access of foreign nationals to these individuals and to DOE facilities are unparalleled among governmental agencies. The Department has become the repository for many of the Nation's most sensitive projects and programs because of its mission and the diversity of its assets, both tangible and intellectual. Also, evolving national policy on arms control agreements directly involves DOE.

DOE counterintelligence implements a DOE-wide program that incorporates counterintelligence awareness training, foreign contacts and travel briefing and debriefing programs, counterintelligence investigations capabilities, active liaison with appropriate Federal agencies on counterintelligence matters, and counterintelligence analysis.

Because of changes in the world order, the counterintelligence element reassessed its priorities and redirected its resources to protecting the Department's technology and intellectual property. The technologies developed or resident in the Department's national laboratories are prime targets of traditional and foreign intelligence service collection efforts. The Department's technology transfer and cooperative research and development agreement programs also present a potential avenue for the illegal acquisition of information vital to the U.S. economy. In order to protect the Department's technology assets, Counterintelli-

gence has refined and increased its efforts to ensure that organizations involved in technological efforts are aware of foreign intelligence service collection methodologies and activities.

Threat Assessment

The Department's Threat Assessment resources are responsible for providing the Secretary and senior DOE officials with timely analyses of potential risks to DOE facilities and interests. For intelligence and law enforcement personnel, DOE conducts intelligence training and awareness seminars regarding nuclear threats, assesses nuclear threats and black market transactions in nuclear material, and manages a special technologies program.

The primary customers for threat assessments are the Federal Bureau of Investigation, the Customs Service, and the State Department. During 1992 and 1993, DOE's assessments discovered no credible nuclear threats or black market transactions. The threat assessment activity also instituted a series of reports on worldwide black market activities in nuclear material.

DOE's special technologies program draws on the research and development expertise resident in its national laboratories to support U.S. intelligence and law enforcement communities. Major accomplishments include advancements in ground-penetrating radar technology and in downsizing an ion-trap mass spectrometer. Because it can detect underground anomalies, intelligence and law enforcement agencies use ground-penetrating radar for tunnel and cache detection; DOE uses it for environmental restoration applications.

ARMS CONTROL AND NONPROLIFERATION

The Office of Arms Control and Nonproliferation serves the U.S. Government arms control and nonproliferation community by providing effective and efficient guidance and technical support. The office pursues the following objectives:

1. To reduce the number of weapons of mass destruction and eventually to eliminate them
2. To prevent the spread of weapons of mass destruction

3. To provide technical leadership in formulating arms control and nonproliferation policy
4. To support international and regional organizations in their obligations to implement and verify compliance with arms control and nonproliferation treaties and agreements
5. To implement the statutory and treaty obligations of the United States
6. To promote the peaceful use of nuclear energy

Arms Control Policy and Technical Analysis

The Department provides direct technical and analytical support for negotiating and implementing arms control and nonproliferation treaties, agreements, and other ongoing activities. It uses in-house expertise as well as the technical expertise of the DOE national laboratories.

During 1992 and 1993, the Department's accomplishments in arms control and nonproliferation included interagency policy development and international negotiations, analysis of treaty and agreement impacts on the Department, programmatic support for improving the Department's techniques and approaches to arms control and nonproliferation, and maintenance of support capabilities on a wide array of arms control and nonproliferation issues.

The Department provided technical and analytical support for many arms control and nonproliferation treaties, agreements, and activities during 1992 and 1993. These included the Strategic Arms Reduction Treaty and the Strategic Arms Reduction Treaty II; the Nuclear Non-Proliferation Treaty and its 1995 Conference and associated Preparatory Committee meetings; the Intermediate-Range Nuclear Forces Treaty; the Limited Test Ban Treaty; the Threshold Test Ban Treaty; the Peaceful Nuclear Explosions Treaty; the Missile Technology Control Regime; the Anti-Ballistic Missile Treaty; the Bilateral U.S.-Russian Defense and Space Talks; the United Nations General Assembly First Committee on Arms Control and Disarmament; Iraq and United Nations Special Commission-related activities; the Conference on Disarmament; the Chemical Weapons Convention and its Preparatory Commission activities; the Bilateral U.S.-Russian Chemical Weapons Destruction Agreement; the Biological Weapons Convention; the Australia Group (export controls on dual-use items related to chemical and biological weapons); the Conventional Armed Forces in Europe Treaty; the Open Skies Treaty; and the Conference

on Security and Cooperation in Europe. The Department also provided technical analysis of verification and implementation issues associated with the Comprehensive Test Ban Treaty.

The Department provided technical and analytical assistance to states of the former Soviet Union, as directed by Congress in the 1991 Soviet Nuclear Threat Reduction Act and the 1992 Freedom Support Act. It helped in many activities, which included dismantling, safely and securely, former Soviet nuclear weapons; establishing the International Science and Technology Center in Russia and the Science and Technology Center in Ukraine to prevent emigration of weapons scientists; destroying Russian chemical weapons; the disposition of Russian highly enriched uranium and plutonium resulting from dismantled nuclear weapons; and collaboration between laboratories in the United States and the former Soviet Union on a series of nonweapons research projects that will reduce the proliferation risks resulting from weapons-related activities of former Soviet Union weapons scientists.

In addition to maintaining readiness to implement the Threshold Test Ban Treaty, the Department provided technical and analytical support to the interagency counterparts including the Department of Defense, the Department of State, and the Onsite Inspection Agency, for implementation preparations for the massive strategic nuclear weapon build-down resulting from both Strategic Arms Reduction Treaties. The Department also analyzed the potential effect of intrusive verification measures mandated by treaties and agreements (such as the Chemical Weapons Convention, the Open Skies Treaty, and the Bilateral U.S.-Russian Chemical Weapons Destruction Agreement) on the Department's ability to protect restricted nuclear weapons data and national security and proprietary information at its weapons facilities and research laboratories. The Department assisted field activities in developing procedures and preparing for the demonstration of treaty compliance without disclosing classified and sensitive information.

Nuclear Nonproliferation Policy

The United States has long been committed to preventing further proliferation of nuclear weapons. In this effort, the Department has the lead responsibility for providing technical and scientific assistance to the U.S. policy community, export control officials, and international nuclear safeguards programs. The Office of Nonproliferation Policy coordinates nonproliferation policy activities. The

Atomic Energy Act of 1954, as amended, and the Nuclear Non-Proliferation Act of 1978, define the Department's principal nuclear nonproliferation responsibilities to include the following:

1. To serve as the principal technical adviser during negotiations with other countries and international organizations for civil cooperation in the peaceful uses of nuclear energy and jointly, with the Secretary of State, to submit proposed agreements to the President
2. To advise on executive branch judgments concerning the issuance of export licenses by the Nuclear Regulatory Commission
3. To monitor and advise on the control of the export of special nuclear materials, components, and equipment and to control exports of nuclear technology
4. To analyze, coordinate the interagency review of, and approve "subsequent arrangements" as defined by the Nuclear Non-Proliferation Act, including important and politically sensitive matters such as plutonium transfers and the reprocessing of spent fuel
5. To provide technical support and assistance to the International Atomic Energy Agency in cooperation with the Department of State and other Federal agencies
6. To promote the Nation's nonproliferation policies by fostering bilateral and multilateral cooperation with foreign governments and organizations
7. To operate a safeguards and physical protection training program for persons from other nations that have acquired or that may be expected to acquire peaceful nuclear facilities and materials

Activist Regional Nonproliferation Policy

The President has called for an activist regional nonproliferation policy, and the Department has worked in conjunction with the Department of State to develop a series of regional nonproliferation initiatives.

The Middle East

In the Middle East, DOE has supported the peace process through a series of conferences on confidence building and verification. These conferences have brought together senior Arab, Israeli, Palestinian, and U.S. negotiators and officials. To facilitate the process, DOE held a 4-day meet-

ing in the United States in September 1993. Planning continues for follow-on meetings. In addition, initiatives are under way for DOE to sponsor a team of national laboratory verification experts to travel through the Middle East to meet and collaborate with government and university experts. Experts from the Middle East will also be invited to review verification technology at workshops held at Sandia National Laboratory.

The Korean Peninsula

On the Korean Peninsula, DOE, in conjunction with the Arms Control and Disarmament Agency, led delegations of experts to conduct simulations and training for representatives of the Republic of Korea in preparation for facilities inspections by the Democratic Peoples' Republic of Korea in the south and for conducting facilities inspections in the north. In 1993, South Korean inspectors visited national laboratories for additional training.

South Asia

In South Asia, DOE has collaborated with the Department of State on seismic verification confidence-building measures, including the upgrade of the seismic-monitoring capabilities of India and Pakistan and plans for jointly monitored activities. The goal is to link India and Pakistan into a comprehensive test ban monitoring network.

East Asia

In East Asia, DOE supports the Department of State in developing a new Pacific community to link North Asian states to address security, arms control, economic, environmental, and other issues. Preliminary meetings were held in 1993; the Department provided technical experts in technology and confidence-building measures.

Latin America

In Latin America, the Department, in conjunction with interagency membership including the Department of State and the Arms Control and Disarmament Agency, initiated discussions in 1993 with senior Argentine and Brazilian officials concerning joint nonproliferation initiatives and the peaceful uses of nuclear energy in Latin America. The ventures support further transparency and international inspection as measures to be used by those two countries to abolish weapons of mass destruction.

Africa

In Africa, DOE is working with the Department of State on plans to eliminate any need for South Africa to have highly enriched uranium. Necessary steps include converting the Safari research reactor to run on low enriched uranium, and completing a program to produce molybdenum-99 for medical use from low enriched uranium targets. These initiatives began during 1993 with plans for continued confidence building and technical support through other measures.

Cooperative Agreements

Through the State Department, the United States concludes agreements for cooperation in civilian uses of nuclear energy according to the requirements of the Atomic Energy Act of 1954, as amended, and of the Nuclear Non-Proliferation Act. The Nuclear Non-Proliferation Act also requires the President to renegotiate existing agreements to conform with the new Nuclear Non-Proliferation Act requirements. The Department provides the technical assistance and support to the Department of State during negotiations of the agreements.

Since passage of the Nuclear Nonproliferation Act, the Department of State, the Arms Control and Disarmament Agency, and DOE have ensured that new agreements with 18 of 30 cooperating partners conform to act provisions. DOE implemented nuclear cooperation agreements with Hungary, Poland, Czechoslovakia, and Finland in 1992. The current agreement with the European Atomic Energy Community expires in 1995; DOE continues to provide technical support to formal negotiations on the renewal of this agreement, which began in 1992. Also in 1993, the Nuclear Cooperation Agreement with Indonesia, which expired in December 1991, was renewed for another 10-year term.

DOE provided technical assistance to the Department of State in negotiating administrative arrangements for the day-to-day implementation of agreements for cooperation, and managed programmatic responsibility for implementing these arrangements.

Subsequent Arrangements

Pursuant to provisions added to the Atomic Energy Act by the Nuclear Non-Proliferation Act, DOE is responsible for approving "subsequent arrangements" for nuclear exports and transfers. Subsequent arrangements involve those arrangements entered into by the U.S. Government with respect to cooperation with another nation or group of

nations involving contracts for furnishing nuclear materials or equipment; such things as approvals for the transfer from one country to another of items over which the United States has consent rights or for which a country has an agreement for cooperation with the United States; arrangements for physical security or safeguards; arrangements for storage or disposition of irradiated fuel elements; or other arrangements that are important to prevent proliferation.

Each such arrangement requires State Department concurrence, as well as consultations with the Arms Control and Disarmament Agency, the Nuclear Regulatory Commission, and the Departments of Defense and Commerce. Before the Secretary enters into some particularly sensitive proposed subsequent arrangements, Congress must be notified following detailed analysis.

During calendar year 1992, DOE reviewed and approved 22 subsequent arrangements, one involving transfer from Switzerland to the European Atomic Energy Community (EURATOM) for reprocessing, and one involving transfer of plutonium from EURATOM to Switzerland. Five subsequent arrangements were pending on December 31, 1992, including one for transfer of plutonium from EURATOM to Switzerland, and one for transfer of spent power reactor fuel from Switzerland to France for reprocessing.

In 1993, DOE approved 20 transfers of nuclear materials from one country to another, 6 sales of nuclear material, 1 arrangement for safeguards, and 1 arrangement for transferring plutonium from France to Belgium.

International Atomic Energy Agency

Through technical and financial assistance, the United States continues strong support for the diverse programs of the International Atomic Energy Agency (IAEA). The United States provided about 25 percent of the IAEA's regular program budget, which funds safeguards and basic technical programs in diverse nuclear fields and applications. These included nuclear power, safety, waste management, basic research, agriculture, industry, medicine, hydrology, environmental analysis, and physical and chemical sciences. The United States also is a principal contributor of voluntary funds to the agency's programs of technical assistance for projects in developing countries. Regular financial support by the United States—through the State Department—for the IAEA totaled more than \$75 million in 1992. This support entailed an assessment of about \$50 million and the balance in voluntary contributions (cash and in-kind). Additionally, in 1992 the United States made a special pledge of \$2.1 million to

support safeguards, this pledge included \$1,000,000 from the Department of Energy.

Recent Events

General Conference

The IAEA is the preeminent international organization responsible for implementing the Nuclear Non-Proliferation Treaty, ensuring that peaceful nuclear cooperation does not assist in nuclear weapons activities, and for promoting the peaceful uses of nuclear energy. Annual policy decision-making concerning the IAEA's program to carry out these objectives is governed by the IAEA General Conference. The Office of Nonproliferation coordinates the Secretary of Energy's trip to the General Conference and provides policy guidance.

The chairman of the Nuclear Regulatory Commission led the United States' delegation, which included DOE's Assistant Secretary for Nuclear Energy, to the 36th General Conference. The conference, held in Vienna, Austria, in September 1992, confronted many significant issues. The most important issue continued to be the inspection of Iraq's nuclear facilities, as called for by U.N. Security Council Resolutions 687 and 707. The Conference adopted a resolution condemning Iraq's noncompliance with its nuclear nonproliferation obligations, and demanded immediate and full compliance and a complete declaration of Iraq's entire nuclear program.

Secretary Hazel R. O'Leary led the U.S. delegation to the 37th General Conference, convened in September 1993. This conference addressed numerous significant issues including support for special inspections of North Korea's facilities; support for a weapons-free zone in the Middle East; enhanced nuclear safety for high-risk reactors in the former Soviet Union and Central and Eastern Europe; strengthening nonproliferation through improved safeguard programs; and the application of peaceful nuclear techniques in developing IAEA member states.

During her address to the General Conference, Secretary O'Leary strongly encouraged the indefinite extension by all parties of the Comprehensive Test Ban Treaty and Nuclear Non-Proliferation Treaty. She reiterated the United States' commitment to nonproliferation, which includes as some of the initiatives critical to continually reducing worldwide nuclear tensions, efforts to strengthen safeguards, limit nuclear weapons materials, enhance cooperation among nuclear suppliers, and increase the use of regional confidence-building measures.

Nuclear Activities in Iraq

United Nations Security Council Resolution 687 of April 3, 1991, demanded that Iraq agree to the destruction of its nuclear, chemical, and biological weapons, its ballistic missiles, and related facilities and components. The Department has provided technical support to the resolution.

In turn, DOE support has included participation in nuclear inspections conducted by the IAEA, as well as inspections concerning ballistic missiles conducted by the U.N. Special Commission.

DOE personnel participated in the initial IAEA inspection of Iraqi nuclear reactors and research center in 1991, and in subsequent inspections. DOE personnel participated in all of the eight IAEA inspections conducted during 1992 and DOE scientists continued to provide analyses of confiscated Iraqi documents, weapons-related machine tools, and other aspects of the Iraqi nuclear weapons program and infrastructure. A DOE scientist also continued to provide onsite technical support to the chairman of the Special Commission and DOE began to examine options for the long-term monitoring of Iraq in accordance with United Nations Security Council Resolution 715.

In summary, throughout 1992 and 1993, the Department continued technical and scientific assistance to U.S. Government departments and agencies to support United Nations Special Commission and IAEA efforts to ensure that the Iraqi nuclear weapons program was dismantled and that it could not be reconstituted in the foreseeable future.

Program Activities

During 1992, technical experts from DOE participated in many IAEA meetings and made significant contributions to technical documents in diverse fields. The Department contributed significantly to IAEA efforts aimed at improving the safety of Soviet-designed reactors deployed in Eastern Europe and the former Soviet Union. This included onsite technical visits, technical assistance in identifying alternatives, assessments, and safety improvements. The Department also continued to participate in special advisory and international working groups and other efforts relevant to DOE programs, such as advanced reactors, basic fusion and physics data, waste management, storage and disposition of spent fuel, and international safeguards technology.

Reduction of Enrichment in Research Reactor Fuel

Increased use of low enrichment fuels for research reactors can significantly benefit nuclear nonproliferation objectives by reducing the international commerce in highly enriched uranium. For this reason, the Department, through the Reduced Enrichment for Research and Test Reactor Program, concentrated its efforts on transferring technology to reactor operators and on assisting in actual conversion activities. Low enriched fuels, which are enriched to less than 20-percent uranium-235, are replacing highly enriched fuels now used in research and test reactors, thus reducing foreign inventories of highly enriched uranium, a proliferation-sensitive material.

The program was initiated to develop fuels technology and related analytical methods and to provide technical assistance to other countries in research reactor conversion. The results of the Department's development activities indicate that all reactors, except those with the most sophisticated reactor designs and high power levels (no more than three, in countries with impeccable nonproliferation credentials), will be candidates for conversion using the technology developed under this program and that these conversions could be made during the 1990s. In 1992, the Arms Control and Nonproliferation program initiated efforts to revitalize this program through increased contacts with foreign governments, research establishments, and reactor operators. In July, 1993, the Argonne National Laboratory signed an agreement with the Russian Research and Development Institute for Power Engineering. They agreed to cooperate in converting former Soviet Union research reactors (and those exported from the former Soviet Union) from highly enriched uranium to low enriched uranium by establishing a Russian Reduced Enrichment for Research and Test Reactor Program patterned after the U.S. program. Additional activities are under way, in cooperation with current and potential commercial producers, to develop the technology for using low enriched uranium instead of highly enriched uranium in targets for producing fission-product molybdenum-99 for use in medical applications.

Offsite Fuels Policy

The Department's policy for the receipt of spent research reactor fuels for reprocessing and storage at DOE sites expired December 31, 1988. Renewal of the policy depends on an environmental review as mandated by the National Environmental Policy Act. In 1992, the Nonpro-

liferation program resumed work on this review and plans to resume receiving of foreign research reactor spent fuel, subject to satisfactory compliance with the appropriate environmental requirements.

Technical Exchanges

The Department continued its program of exchanging technical information on peaceful uses of nuclear energy with other IAEA member countries, a program that supports U.S. nonproliferation policies in several ways. International technical cooperation helps the United States sustain its technological leadership in peaceful uses of nuclear energy, which can be helpful in persuading other governments to support an effective nonproliferation regime. Also, other countries view this willingness to cooperate as evidence of continued support by the United States for article IV of the Treaty on the Non-Proliferation of Nuclear Weapons, which calls for the fullest possible exchange of equipment, materials, and technological information on the various peaceful applications of nuclear energy.

Export Controls and International Safeguards

Export Control Operations

Exports and Transfers of Nuclear Material and Equipment

As required by statute, DOE, along with the Departments of State, Defense, and Commerce and the Arms Control and Disarmament Agency, reviews and recommends approval of nuclear export licenses. The executive branch evaluates export licenses according to criteria mandated by statute. Among other requirements, physical protection must be adequate and IAEA safeguards must be maintained on all peaceful nuclear activities before source material, special nuclear material, production or utilization facilities, or sensitive nuclear technology may be exported to any "non-nuclear-weapons state." According to the Treaty on the Non-Proliferation of Nuclear Weapons, a "nuclear weapon state" is one that "has manufactured and exploded a nuclear weapon or other nuclear explosive device prior to January 1, 1967."

Export Control responsibilities are performed by the Export Control Division in the Office of Export Control and International Safeguards.

Department of Energy Authorizations

Under the Atomic Energy Act, U.S. companies and individuals must receive authorization from the Secretary of Energy before directly or indirectly producing special nuclear material outside the United States. This provision of the act is implemented by DOE regulations under 10 CFR Part 810, which govern U.S. assistance to other countries in producing special nuclear material. In 1992, the Secretary of Energy granted 28 specific authorizations. In 1993, DOE completed 9 specific authorizations; 7 cases are pending.

Of the 28 authorizations granted in 1992, 19 involved nuclear power activities in the former Soviet Union and the countries of Eastern Europe, and 14 of the 19 were efforts to enhance the operational safety of the Soviet-designed nuclear powerplants in these countries. Several of the safety-related proposals involved assistance in building nuclear powerplant control room simulators and devising training programs for plant operators using such simulators. Two authorizations were the first granted for cooperation between U.S. firms and Russian organizations in space nuclear propulsion research and development.

In 1993, DOE completed four safety-related authorizations. Two requests are under consideration.

Commerce Licenses

DOE is the primary reviewer of nuclear-related dual-use exports licensed by the Department of Commerce. Dual-use commodities include items such as computers, machine tools, lasers, and high-speed cameras that have both nonnuclear and nuclear uses. DOE provides both technical and policy guidance to the Department of Commerce for these dual use commodities. In 1992, DOE reviewed more than 6,500 license applications. In 1993, the review caseload increased to 7820 cases completed.

Nuclear Regulatory Commission Licenses

Nuclear Regulatory Commission licenses involve special nuclear material, source material, nuclear reactors and major components, nuclear byproducts, and nuclear moderator material. In 1992, the Nuclear Regulatory Commission referred 94 applications for executive branch review. DOE completed action on 136 applications and 56 applications remained under review. In 1993, the Department reviewed 28 executive branch applications and completed 95 applications; 72 applications remain under review.

Export Control Assistance to the Former Soviet Union

To assist in controlling weapons of mass destruction, related technologies, equipment, and scientific personnel,

the United States has embarked on an export control assistance program for the former Soviet republics, specifically, the four states that inherited nuclear weapons—Russia, Ukraine, Kazakhstan, and Belarus. To establish or enhance export control systems in these countries, the United States has focused bilateral negotiations and concrete training programs on elements of a national export control system. Such systems include licensing review processes, industry outreach programs, enforcement procedures, and the international obligations of nonproliferation treaties and regimes.

Export Licensing and Nonproliferation Information Sharing

In 1993, the Department demonstrated the Proliferation Information Network System, which was developed over several years in an effort to enhance proliferation analysis and policy coordination and cooperation among DOE and selected executive agencies. This DOE-sponsored initiative is a nationwide computerized information network dedicated to the real-time sharing of export licensing and nonproliferation information. This network assists analysts and license-processing officers and is a base upon which DOE is developing additional capabilities for users of export-related proliferation information.

During 1993, the Department installed Proliferation Information Network System workstations at all national laboratories and demonstrated enhanced systems capabilities to Headquarters DOE users.

Nuclear Technology Security

Even though East-West tensions have all but vanished because of the emergence of Eastern Europe and the breakup of the Soviet Union into independent states, vigilance against the proliferation of nuclear weapons cannot be relaxed. In fact, some countries in regions of conflict may be more strongly motivated to acquire nuclear weapons. Historic rivalries and the prestige of nuclear club membership may tempt many countries. As long as this is so, DOE's program of nuclear technology security will be vital to the national security of the United States. DOE's expertise and material resources are committed to U.S. Government efforts to block the acquisition of nuclear weapons capability by non-nuclear-weapons states. DOE's efforts include contributions to the establishment of technical and policy nonproliferation guidelines, as well as participation in multilateral nonproliferation negotiations and in international forums.

Multilateral Nonproliferation Export Controls

DOE plays a leading role for the U.S. Government in multilateral efforts to prevent the spread of weapons of mass destruction and the means to deliver them.

At a meeting of the Nuclear Suppliers Group in Warsaw, Poland, on April 3, 1992, the 27 member states formally agreed on a comprehensive arrangement to control nuclear-related dual-use items. This accomplishment filled a critical loophole in international export controls. DOE provided all of the technical support for the U.S. in this successful effort and was a major developer of the policy guidelines.

A second major achievement at the Warsaw meeting was agreement among members of the Nuclear Suppliers Group to require IAEA safeguards on all nuclear activities in a country as a condition for supplying any equipment or material on the Nuclear Suppliers Group Trigger List. This had been a longstanding objective of the U.S. both for nonproliferation purposes and to make a "level playing field" for legitimate commercial trade. DOE worked closely with other U.S. agencies in convincing hold-out states to join the consensus.

DOE continued its support of the Non-Proliferation Treaty Exporters Committee (known as the Zangger Committee). In 1992 the Committee agreed on an expanded list of items, prepared by DOE, to control the production of heavy water. This marked the successful conclusion of the fourth major Trigger List revision under DOE technical leadership. A new initiative is already under way by DOE to obtain international approval for an expanded list of commodities for several enrichment technologies and for uranium conversion.

During the past year, DOE has been actively involved with key newly independent states of the former Soviet Union and will be a major participant in a concentrated program over the next two years to assist them in establishing effective export control systems.

DOE also has provided technical expertise in other areas of proliferation concern, including modifications to the Missile Technology Control Regime guidelines and control list and to the ongoing work of the Australia Group, which seeks to prevent the spread of chemical and biological weapons.

Coordinating Committee on Multilateral Controls

DOE also provided technical and policy experts to the Coordinating Committee on Multilateral Controls (COCOM), which controls, for national security reasons, exports to the former Soviet republics and Eastern Europe, the People's Republic of China, North Korea, and certain other countries. In light of the breakup of the So-

viet Union into independent republics and disintegration of the Warsaw Pact, COCOM had pared down their export control lists in order to ease availability of modern technology in the former Communist countries. At the same time, DOE assisted COCOM in maintaining controls on such nuclear-related technologies as lasers, high-speed cameras and instrumentation, computers, and numerically controlled machine tools that can help a country design, develop, produce, or test a nuclear explosive device.

Other Technical and Policy Assistance

For other U.S. Government agencies, DOE provides primary technical expertise on all export control matters related to nuclear technology and regulates the export of nuclear technology that could be used directly or indirectly in the production of special nuclear material. DOE has responded to growing concern about power reactor safety in the former Soviet Union and Eastern Europe by developing safety-related criteria to expedite the review and granting of authorizations for U.S. firms to assist in addressing safety deficiencies of Soviet-designed reactors.

International Safeguards and Physical Security

The Atomic Energy Act of 1954, as amended, and the Nuclear Non-Proliferation Act describe the Department's responsibilities for international safeguards and security as key elements of the nuclear nonproliferation regime. DOE's principal mission in this area is technical support in developing and implementing of U.S. Government nonproliferation policy and agreements. This mission is the responsibility of the International Safeguards Division with the Office of Export Control and International Safeguards.

Management of the Department's policy and technology development programs for international safeguards and physical security has achieved a sound technical basis. These programs to strengthen international safeguards and security are implemented through strong technical leadership and active participation in negotiations and collaborations with other U.S. agencies, foreign nations, and international organizations. Events in 1992 required increased support for nonproliferation policy-making activities, including continued participation with the IAEA and the U.N. Special Commission in onsite nuclear inspections in Iraq under U.N. Resolution 687.

In an effort to mitigate the serious effects of budget reductions on IAEA safeguards activities, in 1992 DOE entered into a cooperative arrangement with the IAEA Department of Safeguards to provide extrabudgetary assistance in the form of DOE technical cooperation, in-

kind assistance (such as equipment, and inspector and other technical training) and data base assistance. Under the terms of this 5-year agreement, in 1992 DOE provided \$1 million to the IAEA for safeguards equipment and technology support.

The IAEA has also faced a new technical problem as a result of states with significant, preexisting nuclear activities undertaking full-scope safeguards agreements. In these cases, which could encompass several of the new states formed after the breakup of the Soviet Union that are expected to adhere to the Non-Proliferation Treaty the IAEA must be able to determine the completeness and accuracy of their initial declaration of nuclear material holdings. In order to assist the IAEA in this task, DOE undertook new efforts in 1992 to provide the IAEA with specialized technical expertise, including the conduct of studies and provision of technical experts on the operation of different reactor types and fuel-cycle facilities.

In 1992, DOE also carried out programs of bilateral cooperation with a number of such states in order to facilitate the application of IAEA safeguards under new full-scope safeguards agreements. Existing bilateral safeguards cooperation programs were expanded with Argentina and Brazil, related to safeguards on gaseous diffusion enrichment plants, and new activities were initiated with the Argentina-Brazil Agency for Control and Accounting of Nuclear Material, concerning the provision of safeguards instrumentation and inspector training.

DOE also initiated an extensive new program in 1992 to provide critical technical support to Russia, Ukraine, Kazakhstan, and Belarus to enhance their capabilities to control, account for, and protect civilian nuclear material against theft, diversion, and sabotage. Enhancement of their national systems will support further implementation of international safeguards, including IAEA safeguards as appropriate. DOE undertook extensive contacts with relevant national authorities and nuclear facility operators, including reciprocal visits and seminars on control and accounting procedures and demonstrations of such systems at U.S. nuclear facilities. DOE also held discussions and negotiated draft agreements on formal programs of cooperation encompassing both national and facility systems.

The Department's long-range base program developed new international safeguards technology and concepts and included numerous technology exchanges with other nations. Tasks focused on developing U.S. safeguards technology for worldwide IAEA safeguards applications at advanced nuclear facilities for reprocessing, enrichment, plutonium fuel fabrication, and storage.

DOE technology developed under the long-range base program was transferred to the IAEA through the United States Program of Technical Assistance to IAEA Safeguards (POTAS), a voluntary support program managed by the interagency Technical Support Coordinating Committee and funded since 1977 through the Foreign Assistance Act. POTAS responds to near-term and urgent needs identified by the IAEA Director General. During 1992 and 1993, 38 tasks were completed and, at the end of 1993, 99 tasks were active and 23 U.S. safeguards experts were serving with the IAEA. Since inception of POTAS in 1977, 579 tasks have been completed. Through POTAS, many types of DOE-developed safeguards equipment have been transferred and made ready for use by IAEA inspectors. This equipment was developed primarily at Los Alamos and Sandia National Laboratories. Growing quantities of this equipment are already in use for nuclear materials measurement or for unattended surveillance at safeguarded facilities. The program also continues to train IAEA inspectors and to transfer technologies needed to make safeguards more effective and efficient. Since 1979, all IAEA inspectors have received training at Los Alamos National Laboratory.

As part of its nonproliferation obligations and responsibilities, the Department promotes United States policy through technical and financial assistance to the IAEA to strengthen international safeguards and physical security of nuclear materials.

DOE provides technical leadership in a wide range of IAEA safeguards policy-making forums and participates in bilateral and multilateral negotiations to further strengthen the IAEA safeguards regime. During 1992 and 1993, the Department participated in bilateral safeguards discussions, led by the Department of State, with Japan, Germany, the United Kingdom, France, EURATOM, and Australia. In addition, the Department participated in other bilateral safeguards discussions with Argentina, Brazil, and countries of the former Soviet Union.

The Department also manages the program for U.S. bilateral consultations on physical security and leads U.S. teams in these consultations. The Departments of State and Defense, the Arms Control and Disarmament Agency, and the Nuclear Regulatory Commission participate in this program. During 1992, U.S. teams conducted discussions in France, Germany, Japan, South Korea, South Africa, Hungary, and Czechoslovakia. Japanese representatives also visited the U.S. for similar discussions.

DOE cooperates in developing technology for international safeguards and physical protection with countries worldwide. In 1992 DOE worked under agreements in

effect with the Japanese Atomic Energy Research Institute, the Japanese Power Reactor and Nuclear Fuel Development Corporation, the German Ministry of Science and Technology, the French Atomic Energy Commission, and EURATOM. The Department also has agreements for cooperation with the Argentine Atomic Energy Commission, the Brazilian Nuclear Energy Commission, and the United Kingdom Atomic Energy Authority.

DOE also carries out two international training courses, in cooperation with the IAEA, on state systems of accounting and control of nuclear materials and on physical protection of nuclear facilities. These courses, held every 2 years and 18 months, respectively, train individuals from nuclear programs worldwide, with particular emphasis on technical experts from the developing countries. Although no courses were held during 1992, courses were held in April and May 1993.

SECURITY AFFAIRS

Introduction

The Office of Nonproliferation and National Security, through the Office of Security Affairs, manages the Department's safeguards and security program and is responsible for classification and declassification of information. Although the world appears to be a much safer place today, possible threats to Department interests have not significantly changed over the years. DOE must remain alert to threats posed by terrorists, insiders, and criminals. The Department faces a serious threat by proliferant countries that seek, through a variety of means, to obtain information for designing and manufacturing their own nuclear weapons.

The Security Affairs mission includes protecting DOE assets from the theft, sabotage, or diversion of nuclear weapons or materials, ensuring against the unauthorized access to or theft of classified matter, including information and weapons components, and guarding against hostile acts that may harm national security or the health and safety of DOE and contractor employees, the public, or the environment. The office also seeks to continuously improve policy and guidance for identifying classified and unclassified sensitive information.

Major Initiatives

Significant world changes, such as the breakup of the Soviet Union and the fall of communism in Eastern Europe, dramatically affected departmental programs and missions. Security Affairs is addressing the effects of those changes, including the implications of the reduction of the national stockpile of nuclear weapons; the transition of some key facilities from weapons production to environmental restoration; and the design of Complex-21, the nuclear weapons facilities intended to meet national needs into the next century.

The Department is meeting these challenges aggressively with new security policy, procedures, and systems. Security Affairs established a special safeguards and security planning team that focuses on the major program activities (weapons dismantlement, facility transition, Complex-21, and arms control agreements), assists program and field offices in addressing their needs in each area, and integrates the various program needs.

Facility Transition

Selected departmental programs and facilities have or will be transferred from nuclear weapons research and production to environmental restoration. Operations at several facilities in the nuclear weapons production complex have been or will be shut down.

Complex-21

Complex-21 is the proposed framework for the nuclear weapons complex that would sustain nuclear weapons production capability well into the 21st century. It would be smaller, less diverse, and less expensive to operate than today's complex. This facility will be the state-of-the-art in safeguards and security measures.

Arms Control

International agreements— particularly the Open Skies Treaty (OST) and the Chemical Weapons Convention (CWC)— could significantly affect departmental safeguards and security operations. OST authorizes overflights of departmental facilities, and CWC subjects them to challenge inspections. Security Affairs has assisted in conducting treaty impact assessments, making action plans, and addressing technical matters.

Cost-Saving Initiatives

Security Affairs leads the Department's efforts to reduce the safeguards and security costs of the nuclear weapons complex. It reviews and advises program offices on their respective safeguards and security requirements and budgets and the adequacy of protection requirements.

Safeguards and Security

A primary mission of Security Affairs is to prevent the theft or loss of special nuclear material, nuclear weapons, test devices, and weapons components; the sabotage of Government-owned nuclear facilities; and the unauthorized disclosure of classified or sensitive information under the Department's control. Security Affairs directs the activities necessary for developing new safeguards and security technologies to be used in the field to protect the Department's facilities and activities and to provide the physical protection required by nonproliferation policy.

The office continues to develop its program by improving plans, policies, and programmatic review to ensure the protection, control, and accountability of the Department's nuclear weapons, materials, facilities, and classified matter. During 1992 and 1993, the office modified and approved 33 orders governing departmental safeguards and security. In addition, the office strengthened the personnel security and clearance program; designated 39 training courses for development; balanced program efforts between external and internal threats; improved classified material protection and control; improved nuclear materials accounting and control; and continued safeguards and security research, development, and testing.

While improving the safeguards and security programs at DOE facilities, the Office of Safeguards and Security also enhanced its oversight of the remaining protection elements. The Department maintains a profile system for evaluating the state of safeguards and security at departmental facilities. This system is based on the results of inspection, evaluation, and oversight activities and requires the rating of various aspects of protection at each facility.

Policy Development

Security Affairs made numerous policy revisions during 1992 and 1993 following the Department's issuance of DOE Order 5632.1B, "Protection Program Operations," which refined the responsibilities of protection program

operations, consisting of physical security systems and protective forces. These revisions included the following:

1. The office eliminated the requirement that the armed protective force be used to protect classified information.
2. The office revised policy for the armed protective force for nuclear weapons, Category I and Category II special nuclear material, and radiological and toxicological sabotage targets.
3. Security Affairs modified the clearance requirements for protective personnel so that these requirements are consistent with access requirements.
4. The office issued standards for security helicopters and common procurement guidelines for ammunition.
5. The office reduced overall training requirements by including new protective force position categories, which allow training to be directly applicable to job assignments.
6. By using standardized firearms qualifications courses, the office eliminated the need for developing a custom firearms qualifications course.

The Department's safeguards and security planning includes preventing special nuclear material theft by those who have authorized access to DOE facilities (the potential for such theft is called the "insider threat"). In 1992, the office improved the effectiveness of material control and accountability by revising orders and developing policy guidance.

In response to recommendations contained in the "Report of the Secretary's Safeguards and Security Task Force," the Department is refining the planning process to expedite field office and Headquarters review of safeguards and security plans.

During 1992 and 1993, the Department strengthened and standardized the Foreign Ownership Control or Influence (FOCI) program. It accomplished this by transferring the responsibility for FOCI determination from contracting officers to safeguards and security personnel and by moving toward making FOCI requirements consistent with those of other Federal agencies. Its purpose is to prevent any undue risk to national security that could result if classified information or special nuclear material is made available to DOE contractors or subcontractors that are owned, controlled, or otherwise influenced by foreign governments, individuals, or organizations.

During the past year, Security Affairs developed a prototype personal-computer-based decision support system. When fully implemented, this system will assist safeguards

and security personnel (both field and Headquarters) to determine the risk posed by contractors and subcontractors that have access to DOE classified information or special nuclear material.

Protective Forces

Contractor-operated protective forces numbered approximately 6,500 in 1992. Making extensive use of the Department's Central Training Academy and onsite training facilities, the protective forces routinely undergo rigorous tactical training and testing to maintain constant readiness. The office established policy and criteria regarding instructor training and physical fitness and resolved a number of union issues, such as early retirement, overtime pay, and standardization of protective equipment, safety equipment, and security systems.

The Central Training Academy trains safeguards and security personnel throughout the Department. During 1992 and 1993, the academy's functions increased significantly with the implementation of the Departmentwide Basic Security Inspection Training Program and the Safeguards and Security Strategic Training Plan.

Improvement Activities

During 1992 and 1993, Security Affairs continued to shift its focus toward improving protection against any potential insider threat—cleared personnel who may be, for example, antinuclear extremists or psychotic or disgruntled employees. The office also gave priority to personnel reliability control of classified information and nuclear materials and computer security.

Personnel Reliability

As a result of a revision to the Department's Selective Reinvestigation Program, a backlog of 132,000 reinvestigations existed. During 1992 and 1993, the Department reduced the original backlog of 132,000 reinvestigations to less than 4,000. Although the Department has experienced difficulty in obtaining adequate staff to review and evaluate completed initial investigations and subsequent reinvestigations, the Department alleviated this problem by increasing the use of contractor support staff where appropriate.

In 1989, the Department's Personnel Security Assurance Program was formally approved for implementation. The program's requirements affect personnel who protect, transport, or have direct access to significant quantities of nuclear material; who operate nuclear material

production reactors; or who can damage nuclear weapons production. During 1992 and 1993, Security Affairs strengthened the policies of the program as part of an ongoing process closely connected with Federal directives and judicial decisions.

Access Control

During 1992 and 1993, the Department continued to find mechanisms that will control access more efficiently. One project is examining a means to reduce insider threat, using standard requirements for access controls throughout the nuclear weapons complex.

The Department continued to issue upgraded photo identification badges to all employees and others assigned to its facilities. Each badge is compatible with the access control system; each has a magnetic strip on its reverse side for biometric information and a personal identification number. The Department also continued to issue to the field prescriptive material surveillance procedures that rely on existing and new technologies.

Classified Matter Protection and Control

Information technology and the increasing variety of methods for handling information have increased the probability that classified and unclassified sensitive material will be disclosed without authorization. Throughout 1992 and 1993, the office reviewed existing technologies for protecting classified material and searched for new ones. The Classified Document Control System is one of the new technologies developed by Security Affairs and now in use throughout the Department. It is an automated document storage and retrieval system that obviates the need to retain hard copies of documents. When required, the system can print copies of any document contained within it. The system's security features include layered access control and the tracking of actions taken or attempted by each user.

The office modified accountability requirements to enable departmental organizations to drop unnecessary, outdated administrative procedures. To further this modified accountability, the office conducted seminars in 1992 and 1993 to determine how best to diminish inventories and auditing and to increase protection and control.

Classified Computer Security Program

The Classified Computer Security Program helps to improve the guidance and assistance needed in securing operating facilities. The office continues to study, in depth,

the security weaknesses of the Department's major computer networks. Research and development continues to provide the products that enhance the Department's ability to protect its operating installations and to better assess their level of protection.

Physical Security Systems

The Secretary's Safeguards and Security Task Force, with inspections and policy analyses by the Office of Security Evaluations, determined that DOE should develop a definitive order on physical security systems. Rather, clear, concise wording in the order and manual will reduce field interpretation of requirements and will result in the intended policy implementation. The order will be published in May 1994.

Technical Surveillance Countermeasures Program

The Technical Surveillance Countermeasures Program helps to minimize opportunities for using electronic eavesdropping devices to extract classified or sensitive information. The Department uses a computerized information management system to control and track technical surveillance countermeasures equipment and resources, and uses the Technical Surveillance Countermeasures Threat Assessment Scheduling System, a computerized software package, to assist in setting program priorities for all DOE field locations. These have proven to be excellent tools for the effective control of technical surveillance countermeasures resources.

During 1992, the Department revised the Technical Surveillance Countermeasures Program in several areas. It published DOE Order 5639.5, "Technical Surveillance Countermeasures Program," and it published a revised standards and criteria document. In addition, the Department is revising the *Department of Energy Technical Surveillance Countermeasures Procedural Guide*, which will include the "Operations Manual" and the "Report Writing Guide" as supplements. Upon completion, this new procedural guide will include revised and new program policy and reflect current, more efficient procedures.

After conducting a study, the Technical Surveillance Countermeasures Program Manager concluded that the program should be restructured and consolidated. Team resources and equipment from 17 separate locations would be consolidated into 3 regional offices, which would serve all DOE sites, and thereby the program would become more responsive to changing policy and DOE needs.

Operations Security

National Security Decision Directive 298 of January 22, 1988, mandated the creation of a national Operations Security Program. The Department had already established its own Operations Security Program in 1979, involving both the Government and contractors, which meets the requirements set forth in the 1988 directive. The program provides a systematic and disciplined approach to strengthening the Department's overall security posture while denying adversaries any access to sensitive and classified information.

The "traditional" threat to U.S. security interests changed radically in 1992. As a result, DOE increased its attention to protecting U.S. economic interests from exploitation by both traditional and nontraditional adversaries. The Operations Security Program Manager undertook several actions to familiarize individuals with the changing threat. Among these were advice and assistance visits to 14 DOE sites.

During 1992, the program updated or issued several Operations Security Program policy documents, including DOE Order 5639.7, "Operations Security Program," a new *Operations Security Procedural Guide* in September, and a "Threat Bulletin" in October. The only policy change in DOE Order 5639.7 is the requirement that the Department conduct either a programmatic or a facility operations security assessment every 2 years. The order also incorporated the nationally mandated Counter Imagery Program into the Operations Security Program.

The Open Skies Treaty and the Chemical Warfare Convention were both signed during 1992. (See the discussion under "Arms Control" earlier in this chapter.) Both pose a threat to DOE's sensitive unclassified and classified assets. The Department established a communications network to notify specific individuals of scheduled manned flights over their facilities, and it designated particular individuals to be responsible for ensuring that appropriate actions are taken to negate the overflight threat.

Technology and Systems Development

In terms of technology and systems development, Security Affairs accomplished the following during 1992 and 1993:

1. Published test reports on commercially available video motion detection systems and on improved video storage devices.

2. Developed an explosives test stand that will permit performance testing of commercial explosive detection systems. This capability is not available anywhere in the world and will prove essential for the procurement, testing, and calibration of explosive detection systems.
3. Developed an improved calorimeter for measuring nuclear material quantities, reducing measurement times by 27 to 34 percent.
4. Developed an improved radiation measurement system.
5. Completed the development of a neutron multiplicity counter to improve precision when measuring large plutonium samples.
6. Completed the construction of an automated instrument that measures quantities of plutonium in chloride salts.
7. Completed the evaluation of an advanced plutonium titration system capable of performing high-precision measurements of plutonium metal.
8. Completed the evaluation of a new potentiostat/coulometer for more controlled measurement of plutonium.
9. Released a new version of an intrusion detection system for computers that was developed jointly with the Air Force.
10. Released a user's manual and Version 7.0 of Network Security Monitor, a computer security system that had been developed by the Office of Security Affairs.
11. Released a new version of the Security Profile Inspector for UNIX- and VMS-based computer systems.
12. Developed a text-analysis program for detecting the unauthorized presence of sensitive text on computer systems and networks.
13. Completed a manual for standardizing the installation and testing for a commercially available active infrared intrusion sensor and bistatic microwave intrusion sensor.
14. Completed a technology-transfer package for a video motion detection and tracking system.
15. Developed an access control system that uses biometric credentials, personal identification numbers, enrollment stations, access control booths, and single-door portals to automate access authorization at DOE facilities.
16. Developed an improved nuclear material holdup software program that will help automate the holdup measurement process.

17. Completed the testing of a personnel and material tracking system.
18. Upgraded a vulnerability assessment tool that will help to assess sophisticated scenarios for nuclear material theft.
19. Completed the development of a seminar on measurement controls practices.

Nuclear Materials Accounting and Control

In 1992 and 1993, the Department and the Nuclear Regulatory Commission continued operating the Nuclear Materials Management and Safeguards System—the national nuclear materials information system data base—as an integral part of the Department's safeguards system. This system helps maintain and report the quantitative and financial accountability of all nuclear materials. It is the primary mechanism used by the Government to track nuclear materials for the purposes of safeguards, materials management, production, financial and cost accounting, and for the reporting of inventories and transfers of U.S.-origin nuclear material under international treaties and agreements.

The Department also continued to operate the New Brunswick Laboratory, a technical extension of the Office of Security Affairs that serves as the Department's nuclear material measurements and standards laboratory. The laboratory provides technical oversight in implementing materials control and accountability policy throughout the DOE complex and supports the complex in the area of measurement sciences. The laboratory also provides nuclear material measurement services, assists field offices and DOE contractors, and develops and improves measurement technology and procedures to meet safeguards mission requirements. During 1992 and 1993, the laboratory continued running the Safeguards Measurement Evaluation Program, which addresses faulty and material-specific measurement concerns.

Safeguards and Security Steering Group

During 1992 and 1993, the Department continued its leadership role for the Safeguards and Security Steering Group, which was established by a National Security Council mandate. The steering group ensures that the National Security Council has the information it needs for monitoring and overseeing national programs concerning the security of U.S. nuclear weapon facilities.

Declassification and Classification of Information

Within its jurisdiction, the Department establishes and implements policy for the classification of Restricted Data, Formerly Restricted Data, National Security Information, and certain unclassified but sensitive information (for example, Unclassified Controlled Nuclear Information and Official Use Only Information) acting under the requirements of the Atomic Energy Act of 1954, as amended, and other applicable statutes and executive orders. Security Affairs oversees a multifaceted program to identify the full spectrum of sensitive DOE information, ranging from complex, highly classified nuclear technology to certain unclassified but still sensitive information that, by statute, is not available to the public. Security Affairs is DOE Headquarters' central point of contact for releasing information to the public under the Freedom of Information Act and for mandatory reviews of unclassified portions of classified documents.

General Classification

During 1992, to better protect a complex technology that would be valuable to nuclear proliferants, Security Affairs began a complete revision of the "Production Reactor Guide" (CG-PR-3) to take into account major declassifications and new production reactor technologies that have been developed. The office also initiated classification guides for the new technology of thermionics for space reactor power systems and for space nuclear propulsion. These guides will be particularly important because both will use some Russian technology and support.

The office cut costs significantly by downgrading specific information from *Secret* to *Confidential*.

In 1992 and 1993, the office completed and distributed the classified report "Classification of Radioactive and Hazardous Materials in the Nuclear Weapons Complex." The study determined the extent to which DOE's national security classification rules limit the Department's ability to advise uncleared regulators concerning its use of hazardous and radioactive materials in the nuclear weapons program.

The office also completed a comprehensive study of current DOE classification policies and procedures, examining their adequacy and appropriateness for the coming decade and beyond.

Security Affairs called for declassification proposals from the nuclear weapons complex, so as to make public as much previously classified information as possible with-

out affecting national security. The office will follow a thoroughly coordinated and well-defined process to ensure that the declassified information will not cause undue risk to the Nation's security and defense. Declassifications are four times greater than in the past.

The office issued 4 new guides, updated 15 classification guides for special programs, and made major revisions to two joint DOE and DOD publications: the "Topical Classification Guide for the Nuclear Weapons Complex" (TCG-WM-1) and the "Topical Classification Guide for Boosting and Transfer Systems" (TCG-BTS-1). The Department also is reviewing 24 other classification guides. In addition, the office held technical discussions with foreign nations; these discussions will continue toward developing common international classification guidelines for nuclear weapons information.

To ensure that the Department's classification program maintains its high level of excellence, Security Affairs conducted five classification appraisals of the Department's field office operations.

Because maximizing efficiency is critical in a resource-limited program, Security Affairs continued in 1992 and 1993 its many innovative automation projects that are in various stages of development and implementation. In addition to the Classification Appraisal Follow-up System, the office has developed the Authorized Classifiers Tracking System, the Biweekly Action Tracking System, and the Computerized Action Tracking System—all are fully operational. The Computerized Action Tracking System is a classified document control system that tracks all documents associated with a particular review action and generates all required receipts and labels. These projects will improve upon the paper-based procedures currently being used in the office.

Security Affairs continues to emphasize the education and training of Headquarters and field personnel associated with general classification and unclassified controlled nuclear information (UCNI). During 1992 and 1993, the Classification Training Institute conducted one course for classification officers and analysts, one for Headquarters classification representatives, six for authorized classifiers, seven on UCNI, and several that are specialized. The office has initiated a recertification program consisting of performance-based testing based on the classification guidance used by the authorized classifiers.

To assist various congressional agencies in preparing unclassified documents for public release, Security Affairs completed classification reviews of approximately 20 packages of material from committee and subcommittee hearings.

Unclassified Controlled Nuclear Information

To help minimize the chance of sabotage to sensitive DOE facilities and to decelerate nuclear weapons proliferation in the world, Security Affairs continued during 1992 and 1993 to develop and issue guidance for UCNI.

EMERGENCY MANAGEMENT

Introduction

The Office of Emergency Management (formerly the Office of Emergency Planning and Operations), under the Office of Nonproliferation and National Security, is both the Department's focal point for emergency preparedness and response activities and the interagency point of contact for such activities. Its main goal is to ensure that DOE's responses to all emergencies are integrated and coordinated. Its activities encompass planning, development, readiness assurance, and testing of the Department's emergency response capabilities; it ensures that the Department of Energy can adequately respond to events ranging from widespread fuel supply disruptions or power outages to a large-scale hazardous material or radiological emergency.

These events fall into three broad categories: operational, energy, and continuity-of-government emergencies.

Operational emergencies are accidents, incidents, events, or natural phenomena that can seriously degrade the safety or security of DOE facilities. These events involve DOE nuclear reactors; other hazardous DOE facilities; DOE-controlled nuclear weapons, components, test devices, and nuclear materials; safeguard and security events; and transportation accidents.

Energy emergencies are actual or potential disruptions to the Nation's energy supplies resulting from natural disasters, national security situations, malevolent acts, technical malfunctions, or economic boycotts.

Continuity-of-government emergencies are large-scale national security incidents that threaten or affect the continuity of the Federal Government's operations.

Emergency Management has implemented an Emergency Management System (EMS). EMS provides the framework for developing, coordinating, and directing the Department's planning, preparedness, and readiness assurance activities to meet all types of emergencies.

Responsibilities

Emergency Planning and Operations operates a newly constructed Emergency Operations Center at the Forrestal Building in Washington, D.C., 24 hours per day and maintains the Technical Support Center in the Department's Germantown, Maryland, facility, which also functions as the alternate Emergency Operations Center. The Technical Support Center will be renovated and upgraded in 1994.

These state-of-the-art facilities provide senior managers with many information processing, communications, and data transfer capabilities. These include video teleconferencing throughout the Emergency Operations Center. The Emergency Operations Center was designed to allow the Department to manage simultaneous events and have all informational tools available for decision-makers during crises.

Concept of Organization During Emergencies

During emergencies, an Emergency Management Team is convened at the Department of Energy Headquarters. The Headquarters team consists of two elements: the Executive Team and the Technical Operations Cadre. The Executive Team is composed of senior managers at the assistant secretary and office director level and it is usually chaired by the under secretary. The Technical Operations Cadre is composed of personnel from the relevant program office, as well as specialized Headquarters offices. The Executive Team provides strategic direction to the emergency response and evaluates the broad impacts of the emergency on the DOE or on the nation's energy supplies. The Technical Operations Cadre monitors the emergency in terms of worker and public health and safety, energy systems, and the economy. It oversees and coordinates national assistance to the affected DOE site, state, or region. The Technical Operations Cadre also provides information to the White House, Federal agencies, Congress, state and local officials, and the public.

Operational Emergency Planning and Preparedness

In 1992 and 1993, Emergency Management continued to modify emergency management programs, based on experience and current policies. For field and Headquar-

ters emergency management professionals, the office conducted workshops and seminars on the criteria for an adequate emergency preparedness program. To ensure that current policies are administered, the office continually updates its implementing guidance.

Emergency Management continued its efforts to develop and complete the series of departmental directives that establish requirements for the Emergency Management System.

Departmental Emergency Readiness Assurance

Emergency Management maintained the Department's emergency readiness assurance by implementing an extensive drill and exercise evaluation program at its various sites and facilities. During 1992 and 1993, the office evaluated six full field exercises. These exercises included one at the Fernald facility in Cincinnati, Ohio; two at the Savannah River facility in Aiken, South Carolina; one at the Pantex facility in Amarillo, Texas; and Diamond Flame (a nuclear weapon exercise), and TRANSAX '92 (a radioactive waste transportation exercise) in Idaho Falls, Idaho.

Emergency Management also appraised field emergency management programs. This effort enabled policymakers to review the plans and procedures of emergency management programs and to offer constructive direction and guidance toward an effective emergency management program.

Energy Emergency Responses

Hurricanes and Typhoons

In August and September 1992, Hurricanes Andrew and Iniki and Typhoon Omar caused enormous property damage and widely disrupted power systems in the southeastern United States, Hawaii, and Guam, respectively. Even before Hurricane Andrew hit land, DOE staff deployed to Federal Emergency Management Agency (FEMA) Region IV Headquarters in Atlanta. Staff also deployed to State Emergency Operating Centers in Tallahassee and Baton Rouge.

DOE staff in Washington coordinated information exchange through the Emergency Operations Center at Headquarters and with staff at FEMA headquarters. DOE staff, deployed to the regions and to the FEMA disaster

field offices, coordinated responses with state emergency officials and representatives from power companies, petroleum pipeline companies, and refiners. In the aftermath of Hurricane Andrew, DOE field representatives located fuel and emergency generators to serve airports and radio stations. When a major petroleum pipeline company lost electric power for its mainline pumps, DOE field representatives put pipeline executives in touch with electric utility executives to speed power restoration.

After Hurricane Iniki and Typhoon Omar destroyed vast portions of the Hawaiian Islands and Guam, respectively, DOE staff from the San Francisco Support Office and the power marketing administrations identified the requirements for electric utility restoration and arranged transport by the U.S. Air Force. They also helped other regional Federal officials to establish and coordinate restoration priorities in conjunction with Hawaiian officials and FEMA.

Potential Propane Shortfall

DOE staff routinely monitored propane supply and distribution, particularly during the fall and winter. While total propane supplies seemed adequate in the fall of 1992, Emergency Management learned about a potential shortfall in the midwestern United States because of heavy demand for crop-drying. This spurred a more intensive DOE effort to determine the potential for propane shortages and the outlook for mitigating them.

Los Angeles Riots

During the Los Angeles riots, Emergency Management remained in close contact with state emergency officials, alerting them to requests by the energy industry for state police or National Guard assistance in protecting key energy facilities.

National Defense Executive Reserve

During 1992 and 1993, Emergency Management trained 43 National Defense Executive Reserve members at the DOE Central Training Academy in Albuquerque. Since the start of the reserve training program in 1988, more than 150 reservists have completed emergency response training, including both orientation and advanced sessions.

To better prepare for today's changing domestic and foreign environment, Emergency Management reviewed ways to use industry officials more effectively in an emergency.

Federal Response Plan

The Draft Federal Response Plan (FRP) of April 1992 established the basis for Federal assistance to a state and its affected local governments when they have been hurt by a disaster or emergency.

The plan groups the types of Federal assistance under 12 Emergency Support Functions (ESFs). Emergency Support Function 12 (Energy) recognizes that adequate energy supplies are essential to maintain life, support essential public services, and maintain economic strength. To prepare for its part in the FRP, Emergency Management is designing a regional program to coordinate planning among FEMA regions, DOE Headquarters, and the agencies that support DOE in ESF 12.

In 1992 and 1993, Emergency Management began developing the standard operating procedures that DOE will use to alert, mobilize, deploy, and communicate with appropriate individuals and organizations during severe crises. DOE will test these procedures in disaster exercises.

In 1992 and 1993, Emergency Management signed a memorandum of agreement with the Department's Office of Energy Efficiency and Renewable Energy to plan for field support and to ensure that the Department has a voice in the regional planning sponsored by FEMA.

In 1993, Emergency Management accomplished the following:

1. Defined DOE responsibilities and support requirements under the FRP
2. Updated the ESF 12 Annex to the FRP
3. Assessed and analyzed DOE requirements to support other ESFs
4. Reviewed all applicable DOE orders to ensure that they adequately address DOE support to the FRP
5. Developed a DOE Headquarters FRP Procedures Manual; and, working with FEMA regional staff, began to develop ESF-12 operating plans for each FEMA region
6. Participated in RESPONSE-93, a multiregion, multiagency earthquake response exercise sponsored by FEMA and the State of Utah to test FRP responsibilities and procedures

Emergency Management will continue to incorporate the experience, emergency plans, and procedures of other organizations (Federal, state, and private industry), and other information and data that will aid in assessing and implementing a Federal Response Plan.

Government-Industry Energy Vulnerability Program

Energy Infrastructure Vulnerability Assessments

To sharpen the focus of its emergency preparedness and response activities, Emergency Management designed and sponsored an exercise that postulated a 2- to 4-week disruption to the Trans Alaska Pipeline. Participants included pipeline operators, State of Alaska emergency personnel, DOD staff, and emergency personnel from various West Coast jurisdictions that depend on Alaska crude oil. The exercise demonstrated the value of training and the need for prior planning among emergency personnel from the various jurisdictions that would become involved in such an emergency.

Sensitive-Information-Sharing Networks

In response to the threat of terrorism to energy production and delivery networks, the Department shared unclassified threat information with energy industries, using electronically disseminated threat advisories. In 1992, the Department began to sponsor classified threat briefings to energy industry security groups whose members had been granted clearances for that purpose.

State and Regional Liaison

Seminars and Simulations

Emergency Management continued its energy preparedness seminars and simulations, which began in 1988. State and local officials used these seminars to test their emergency plans and to incorporate lessons from natural disasters into these plans.

During 1992 and 1993, Emergency Management conducted four regional seminars for Federal, state, local, and private industry officials.

In October 1992, Emergency Management conducted the annual Winter Fuels Outlook Conference. Federal, state, and energy industry officials attended the conference, which was cosponsored by the National Association of State Energy Officials. Such conferences have been held yearly since the heating fuels emergency in 1989.

In 1992, FEMA and DOE sponsored a focus group of state energy and emergency officials. This focus group incorporated energy issues into the existing curricula for emergency management courses conducted at FEMA's Emergency Management Institute.

In 1992, in view of changes required under the Clean Air Act, Emergency Management presented a petroleum refinery training course for DOE and Energy Information Administration staff to examine the impact of the act on the refining industry.

Earthquake Preparedness

In April 1992, an earthquake measuring 6.9 on the Richter Scale struck 30 miles southeast of Eureka, California. The Department's assessment and response to this event was greatly aided by an earlier simulation conducted in 1992 by Emergency Management in anticipation of such an event. In 1993, the Los Angeles earthquake provided an opportunity to implement lessons learned from the earthquake simulation conducted in 1992.

State Planning Efforts

Emergency Management continued the State Planning Initiative to foster the development of Energy Emergency Plans in all states. In 1992, Emergency Planning and Operations provided hands-on technical assistance to states that did not have Energy Emergency Plans.

International Energy Emergency Preparedness

International Energy Agency

In the fall of 1992, DOE participated in AST-7, the seventh test of the International Energy Agency's Emergency Sharing System. Such tests help ensure that the system is ready to use. The Agreement on an International Energy Program calls for the system to be triggered if there is at least a 7-percent disruption of normal oil supplies for Agency members as a whole, or for any single Agency member. The system provides for the collection of emergency data from participating oil companies and International Energy Agency members, and specifies guidelines for allocating available supplies among members and rebalancing supply inequities.

As a member of the design group for the test, DOE advocated emphasis on participants' training in system

procedures, while minimizing burdens on individual oil companies. The Department helped train participants in Paris and Washington. During the 2-week operational phase, the Department simulated a 117-million-barrel (16-million-metric-ton) drawdown of the Strategic Petroleum Reserve as part of the U.S. response to the postulated disruption of normal supplies.

North Atlantic Treaty Organization

Within the North Atlantic Treaty Organization, the Department represents the United States in the Petroleum Planning Committee, which it currently chairs, while participating in the organization's oil-crisis planning. The Department helped develop new petroleum crisis arrangements in coordination with U.S. industry executives recruited by DOE for the organization's Petroleum Experts Group.

National Petroleum Council

In 1992, an ongoing study sponsored by Emergency Management and other DOE offices reviewed changes that will affect the production of refined petroleum products through the year 2010.

National Security Emergency Preparedness Program

Continuity of Government

In February 1992, the Energy Functional Group of the National Emergency Management Team sponsored a workshop on energy system vulnerabilities for the entire community involved with the Continuity of Government Program.

National Security Emergency Preparedness

To improve energy emergency preparedness in today's global environment, the Department worked with other Federal agencies on a National Security Council committee to implement the President's national security strategy, which relies on strategic deterrence, crisis response, and adequate defense and civilian defense-related capabilities to reduce the global threat to the United States and to demonstrate U.S. capability to respond to rapid global changes.

For the seventh consecutive year, the Department took part in the Global Series at the Naval War College in Newport, Rhode Island. This annual exercise tests a strategic framework for addressing energy security and fuel supply issues, particularly oil. Throughout the series, the Department was able to make military and civilian agencies more aware of how critical oil is to national security and the national industrial base, demonstrating that infrastructure and critical technologies such as transportation and communications depend on energy.

Electric Service Priority

DOE developed the Communication Electric Service Priorities program in cooperation with the National Communications Systems and the Energy Task Forces of the National Security Telecommunications Advisory Committee. This program addresses the energy supply requirements of the telecommunications industry regarding national security and emergency preparedness. In 1992 and 1993, after field testing a pilot implementation plan in Maryland and New Hampshire, Emergency Management began to implement the program.

Initiatives and Studies

Energy Industry Liaison and Data Analysis

The Department's liaison with energy industries promotes coordinated responses to emergencies. In 1993, DOE strengthened such contacts considerably during the Los Angeles riots, the 6-month-long coal strike, and the summer flooding in the Midwest, when the Department frequently responded to industry officials' requests for information. Industry officials willingly shared important information with the Department on electric power, natural gas, petroleum, and solid fuels.

Interagency Liaison

Building on interagency coordination developed during Operation Desert Storm, Emergency Management used working agreements with the Department of Transportation to help motor carriers obtain waivers of truck driver restrictions to deliver needed emergency fuel supplies to

residential customers, help the U.S. Coast Guard prioritize ship movements so emergency fuel supplies could be delivered promptly, and help the Bureau of Customs and the Maritime Administration speed processing of requests for waivers of the Jones Act for fuel shipments. As part of Federal Response Plan activities, Emergency Management worked closely with the U.S. Army Corps of Engineers and the General Services Administration to secure portable generators and fuel supplies for victims of natural disasters.

Natural Gas Program

Federal Energy Regulatory Commission Order 636 (April 1992) extended the deregulation of natural gas transportation that was begun in 1984 (order 436). Deregulation has created ready access; pipeline companies mainly transport gas rather than resell it, because now they own very little of the supply. This situation is expected to restrict pipeline companies' ability to redirect gas to high-priority customers in an emergency. Predetermined curtailment plans that were established by the pipeline industry are now moot.

Deregulation also caused the Department to consider the emergency provisions of the Natural Gas Policy Act of 1978 (sections 302, 303, and 304). Emergency Management remains in close contact with natural gas producers, pipeline companies, and local distributing companies to monitor natural gas supplies and availability. In the past year, several pipeline ruptures have caused temporary interruptions in service. System redundancies allow supplies to continue to move while repairs are made. Emergency Management and other DOE offices continue to assess ways to overcome temporary supply imbalances and to identify the options for Government assistance.

Natural Disaster After-Action Assessments

Emergency Management prepares after-action reports that describe the effects of disasters on energy systems, DOE's response to the disaster, and lessons learned at Headquarters, at FEMA, and in the field. In 1993, Emergency Management prepared after-action reports on energy systems affected by the summer floods in the Midwest and ice storms and cold weather in the East. In general, energy systems are redundant and flexible and can quickly adjust to and work around localized interruptions.

CHAPTER 10

ENVIRONMENTAL MANAGEMENT

The Environmental Management Program is responsible for identifying and reducing risks and managing waste at 137 sites in 34 states and territories where weapons research and development or production have resulted in radioactive, hazardous, and mixed waste contamination. Portions of the more than 3,300 square miles (5,300 square kilometers) of land managed by the Department contain contaminated surface or groundwater, soil, and structures. The number of sites in the program continues to grow as facilities are transferred from other departmental programs (primarily the defense weapons complex) to be cleaned up and closed down.

The program's main challenge is to balance technical and financial realities and develop a strategy that enables the Department to meet its commitments to the American people. The Environmental Management Program must meet legal requirements of 71 compliance agreements as well as many environmental regulations, and these requirements continue to grow. The major responsibilities of the Environmental Management Program are waste management, environmental restoration, technology development, facility transition and management, and public participation.

To provide a measure to use in assessing progress, the Assistant Secretary has established the following goals for the Office of Environmental Management (EM; formerly the Office of Environmental Restoration and Waste Management) program:

1. Control the urgent risks in the system
2. Make worker health and safety paramount
3. Be outcome-oriented and get tangible results
4. Establish a system that is *in control*, managerially and financially

5. Focus on technology development to solve real problems
6. Establish a much stronger partnership between DOE and its stakeholders

In February 1994, a new document, *Environmental Management 1994*, was published in response to new reporting requirements under the National Defense Authorization Act for Fiscal Year 1994. This report will be issued each year, within 30 days of the submittal to Congress of the President's budget request, to report on the program's progress and plans and to provide information on projects that have varied significantly from planned costs or schedules.

Another report required by the National Defense Authorization Act for Fiscal Year 1994, the *Baseline Environmental Management Report*, will be submitted to Congress in March 1995. This report will detail the total long-term requirements for the environmental management of the Nation's nuclear weapons complex, including annual budget requirements to meet compliance commitments, the total cumulative costs of program requirements, and the required tasks. The last estimate of the Department's total environmental liabilities throughout the weapons complex was prepared in 1988, before the end of the Cold War and with dramatically different assumptions about the future of the complex.

The following pages describe the Environmental Management planning process as it existed during the 1992–1993 period covered in this *Annual Report*. That planning process has evolved, and in 1994 the Environmental Management program was reorganized. This reorganization will be detailed in the 1994 *Annual Report*.

PLANNING AND RESOURCE MANAGEMENT

The Deputy Assistant Secretary for Planning and Resource Management is responsible for managing, coordinating, and supporting the Office of Environmental Management (EM) through planning, financial management, and administrative management. These responsibilities are handled by three offices: the Office of Planning, the Office of Financial Management, and the Office of Administrative Management. The Safeguards and Security staff assigned to the Deputy Assistant Secretary support all EM programs and activities.

Planning

The Office of Planning develops, analyzes, and coordinates policy issues for the Environmental Management Program and supports implementation of policies through effective planning. This office produces documents that both drive and report on the EM planning process. One of these planning documents in previous years was the *Office of Environmental Restoration and Waste Management Five-Year Plan*, which detailed short-term program goals, issues, and strategies. The Five-Year Plan for 1994–98 was released in January 1993. This was the fourth Five-Year Plan published by EM and was mandated by Congress under the National Defense Authorization Acts for 1992 and 1993.

Other elements of the EM planning process that are managed and overseen by the Office of Planning are the *Environmental Restoration and Waste Management Strategic Plan*, the *Environmental Restoration and Waste Management Safety and Health Five-Year Plan*, Roadmaps, Activity Data Sheets (ADSs), and a range of public involvement activities. These documents and activities serve to coordinate and unify the separate cleanup efforts of the EM program offices (Environmental Restoration, Waste Management, Facility Transition and Management, and Oversight and Self-Assessment).

The March 1993 EM strategic plan outlines EM senior management's vision and goals for the program over the 30-year planning horizon (through 2019). It built upon the first EM strategic plan, published in July 1992, by identifying eight strategic objectives that must be accomplished to complete the EM mission (for example, regulatory compliance, elimination of unacceptable risk, and pollution

prevention). The strategic plan discusses these objectives in terms of issues, resolution strategies, and success indicators (that is, how DOE will define the achievement of each objective).

Roadmaps identify key issues affecting cleanup progress at DOE sites and Headquarters and propose strategies for their resolution. Roadmaps play an important integrating function within EM as issues identified are elevated for resolution at the appropriate level of management. In 1992, the Office of Planning began enhancements to the roadmapping process by developing Integrated Roadmaps, which will expand the role of the roadmapping process by including a more comprehensive and integrated approach sitewide, as well as options analysis, risk assessment, and land-use planning scenarios.

Another important source of information for both the EM planning and budgeting processes are Activity Data Sheets, which were developed in 1989 and are used to collect project-specific scope, cost, schedule, and regulatory data. These data are critical in developing the EM budget. The Office of Planning also uses Activity Data Sheets data to develop its planning documents and activities.

To ensure that EM meets its goals, the Office of Planning is working to streamline EM's planning process. As of mid-1993, the Office of Planning is studying ways to make the planning process more results oriented, such as increasing accountability at all levels of management and giving the operations offices more flexibility in developing and implementing site cleanup activities. The new EM planning process will incorporate strategic planning at the national and site levels and analysis of issues that could affect progress and will consider future land use options. The process will meet the reporting requirements of specific legislation (for example, the National Defense Authorization Act and the Government Performance and Results Act) and will be geared toward meeting stakeholder and program needs.

In 1992, the Office of Planning published the first *Environmental Restoration and Waste Management Safety and Health Five-Year Plan*, which delineated safety and health issues and program initiatives to reduce and manage safety and health risks associated with EM activities for 1994–98. In late 1991, the Secretary directed all DOE programs to develop safety and health plans (under overall direction of the Office of Environment, Safety, and Health) to be incorporated into a departmentwide plan. Prior to publication of the plan, EM safety and health activities were developed and implemented separately by the program offices and field operations offices. The EM safety and

health Five-Year Plan represented an important first step toward increasing attention on EM-wide safety and health issues and developing unified strategies to resolve them.

In September 1993, the newly formed EM Safety and Health Steering Committee completed the *Environmental Restoration and Waste Management Safety and Health Five-Year Plan* for 1995–99. It provides a detailed strategy for improving the safety and health of both the DOE and contractor work forces.

To improve stakeholder and public participation in the EM program, in 1992 and 1993 the Office of Planning coordinated meetings with established EM stakeholder groups—the State and Tribal Government Working Group and the Stakeholders’ Forum—to discuss EM planning issues. These groups’ comments and suggestions contributed to the development of the strategic plan and other documents.

In 1992, the Office of Planning carried out two new projects designed to involve the public in its activities. After coordinating a program in which students across the country reviewed the 1993–97 Five-Year Plan, the office worked with students in the Washington, D.C., area to develop a student version of the 1994–98 Plan. In addition, 1992 marked the first year that EM published a Comment Response Document, which addressed public comments on the 1993–97 plan. These initiatives continued in 1993. The Department published a document addressing public concerns regarding the 1994–98 Five-Year Plan in September 1993.

In early 1993, the Office of Planning led an effort to involve stakeholders in EM planning, budget development, and priority setting. This effort marks a major shift in the way that EM does business. From now on, stakeholders will be involved in almost every aspect of EM planning and decision-making.

Financial Management

The Office of Financial Management manages, integrates, and coordinates EM and field financial management activities, including financial policy development and analysis. Major responsibilities of this office include coordinating all EM budget activities, integrating the EM Five-Year Plan into the EM budget process, and coordinating major field project management activities as they relate to Major Systems Acquisitions under DOE 4700.1.

The internal review budget is prepared after all EM Activity Data Sheets have been finalized. This budget is sub-

mitted to the Controller’s Office for review; the Assistant Secretary for EM then makes a presentation to the Secretary on responses to issues raised by the Controller. Based on Secretarial guidance, a funding level is established and an Office of Management and Budget (OMB) budget is prepared and submitted. Following OMB review and hearings, the executive branch makes a decision regarding the final budget, which is then prepared and submitted to Congress.

Administrative Management

The Office of Administrative Management provides cross-cutting support services to EM headquarters. These activities include personnel actions, facilities management, manpower and organizational analysis, contracts management, and information resources management.

The Office of Planning and Resource Management processes all personnel actions for EM headquarters. In addition to its usual personnel operations during 1992 and 1993, the office processed the hiring of 146 former employees of the New Production Reactor Office.

The facilities management staff of the Office of Administrative Management oversees the Trevion II building in Germantown, Maryland, where the majority of EM’s employees work. The Acquisition Office in 1993 awarded and began administration of a large support-services contract that provides the Office of Planning and Resource Management the majority of its contractor support. The Information Resources Management Office began to design a Corporate Information System to integrate and replace the multiple systems that currently exist in EM.

The Safeguards and Security staff assigned to the Office of the Deputy Assistant Secretary for Planning and Resource Management supports all EM programs. It manages and implements the EM Headquarters security program and also ensures compliance with departmental security requirements, supports Headquarters and field planning for and implementation of protection at EM facilities, and supports facility transitions.

During the 1992–1993 reporting period, field activities by the Safeguards and Security staff emphasized identifying and using opportunities to reduce protection costs and supporting protection planning for the transfer of the Rocky Flats plant to EM. At Headquarters, activities focused on supporting self-assessments of EM security programs and implementing measures to reduce the number and level of security clearances held by EM program staff.

Staff in both areas worked on protection policy development and reviewed the proposed policy for its impact on and relevance to EM programs and missions.

OVERSIGHT AND SELF-ASSESSMENT

The Office of Oversight and Self-Assessment, renamed the Office of Compliance and Program Coordination, provides appraisal and assessment, policy and guidance, and technical support and assistance for activities that span EM line organizations in the areas of environment, safety, and health; engineering and cost management; conduct of operations; quality assurance; and self-assessment. The office's mission is to help EM organizations in Headquarters and the field comply with applicable laws, regulations, DOE orders, and accepted industry standards and practices and to help EM achieve excellence in programmatic activities. It tracks the performance of EM's business, identifies common problems and their possible solutions, and provides technical assistance to the line organizations.

To help meet EM's commitment to worker safety and health, the Office of Oversight and Self-Assessment has either established or led the following activities:

1. The EM Health and Safety Steering Committee and subordinate working groups
2. The DOE Hazardous Waste Operations and Emergency Response (HAZWOPER) Safety and Health Technical Guide
3. Medical surveillance and exposure assessment guidelines for EM hazardous waste workers
4. Initiatives for the international meeting on the use of biomarkers for worker health monitoring
5. Draft safety and health performance elements for EM managers

The office has also completed a draft document to provide EM guidance on the integration of the many safety and health requirements contained in the Department's directives system. This document establishes uniform guidance on minimum criteria for safety and health documents that identify and establish procedures to control hazards (both radiological and nonradiological) for all EM facilities. The office has created departmental working groups to coordinate and review contractor implementation plans required by various nuclear safety orders. Since early 1992, the office has been developing a means of

ensuring that EM facilities and projects operate using best industry standards and practices that reach beyond those specified in existing DOE orders, as required by the Department's response to Defense Nuclear Facilities Safety Board Recommendation 90-2. This recommendation, based on the Defense Nuclear Facilities Safety Board's initial review and evaluation of the content and implementation of standards and requirements related to the design, construction, operation, and decommissioning of DOE's defense nuclear facilities, called for (1) identification of specific standards and requirements that apply to DOE facilities, (2) assessment of the adequacy of those standards and requirements in protecting the health and safety of workers and the public, and (3) determination of the extent to which the standards and requirements are being implemented.

The Office of Oversight and Self-Assessment's Office of Operations Assessment has visited every DOE operations office with EM-funded activities and has assessed 23 production, remediation, laboratory, and decommissioned facilities. During these assessments, more than 200 persons have been trained in operations assessment techniques to provide consistency in measuring contractor performance against the guidance in DOE Order 5480.19, "Conduct of Operations Requirements for DOE Facilities." These assessments, which provide an evaluation of management and organization of EM-funded field activities, are conducted to ensure that an acceptable level of safety is provided to workers, the public, and the environment. In addition, through consultative services, technical assistance is provided to operations offices and contractors in developing plans for operations improvement. This office is also the focal point and technical advisor for the EM program managers and counterparts within DOE on matters that affect radiological controls programs, including management, worker training, and the *DOE Radiological Control Manual*.

DOE has established agreements-in-principle with 12 states to provide technical and financial support for oversight of DOE monitoring of water, air, and soils and for emergency response planning for onsite incidents. The agreements-in-principle also provide access to DOE facilities. In 1993, EM conducted agreement-in-principle implementation reviews in five states (Idaho, New Mexico, Texas, Tennessee, and Nevada). EM conducted the reviews in cooperation with the states to update EM on the status of agreement-in-principle program activities being conducted by the states and to identify actions that could be taken to implement the programs more effectively. The office plans additional reviews.

To reach its goal of managerial and financial control, EM established a cost reduction task force to serve as the focal point for all cost reduction, project management, and productivity improvement initiatives. The task force has set up a program to substantially reduce costs and improve management effectiveness, cost controls, and productivity in EM headquarters and the DOE operations offices. The task force works to identify permanent cost savings, formulate plans to implement the cost reduction proposals, and establish a performance measurement system to monitor progress. To facilitate the proposed cost reductions, the task force assists EM managers by providing them with additional analysis and information.

In 1993, EM also established and held the first annual Cost Management Conference for EM only. These meetings will provide a forum for exchanging cost management techniques and innovations among experts in the field.

The office also issued the EM Policy on Cost and Schedule Estimating and Analysis for EM headquarters and operations office managers. This policy emphasizes existing DOE-wide policies and sound cost management principles as they apply to EM activities. The policies address development, validation, and control of costs and schedules. In addition, EM developed the Independent Cost Estimate Review Handbook, an indirect-cost guide, and other documents to help EM managers understand effective cost management principles.

The Office of Oversight and Self-Assessment carries out the National Environmental Policy Act (NEPA) Compliance Officer function for EM. This function has been established to ensure compliance with the Council on Environmental Quality's and the Department's NEPA regulations. The function includes reviewing the technical validity of EM's NEPA documentation, as well as providing guidance and standards on the DOE NEPA process. In 1993, the office issued a set of criteria and requirements to determine whether operations offices had proper procedures in place to receive delegation of certain approval authorities under the Department's and EM's NEPA compliance program. These delegations have allowed early decisions on the level of NEPA reviews to be conducted by field organizations and have streamlined part of the NEPA review process.

EM staff also provided technical reviews and concurrence on approximately 75 Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) documents (proposed plans, remedial investigation and feasibility study documents, CERCLA records of decision, and integrated CERCLA/NEPA documents) to ensure reasonable, technically feasible, and cost-effective remediation decisions.

The office prepared a draft guidance document containing recommendations to effectively integrate NEPA values into the CERCLA process in accordance with DOE policy for those remedial actions requiring NEPA review at the environmental-impact-statement level. The draft guidance document received extensive Headquarters review, and the comments received are currently being resolved before the document is provided to the operations offices for additional review. The office is also developing guidance on integrating NEPA values into the CERCLA process for those remedial actions requiring NEPA review at the environmental-assessment level.

The Defense Nuclear Facility Safety Board, in its Recommendation 90-2, identified DOE Order 5820.2A, *Radioactive Waste Management*, as needing revision. In an effort to maintain objectivity in revising the order, the office established a steering committee, made up of representatives of the DOE program offices, including Environment, Safety and Health, Defense Programs, Nuclear Energy, Energy Research, Civilian Radioactive Waste Management, General Counsel, and Human Resources, to guide the revision process. Other EM headquarters program offices are also involved. In addition, many internal departmental stakeholders are involved on technical working groups actually revising the chapters in the order. The process developed by the steering committee is consistent with the Department's Directive System Specification and is attempting to involve all stakeholders in the process. A major effort will involve bringing stakeholders external to the Department into the process. Activities to develop a stakeholder involvement plan that outlines the manner in which the public is involved are under way.

WASTE MANAGEMENT

The Waste Management Program has the responsibility to protect human health and the environment from the hazards of wastes at EM/field sites by providing an effective and efficient system that minimizes, treats, stores, and disposes of those wastes.

Waste management provides for the treatment, storage, and disposal of the Department's radioactive, hazardous, mixed (radioactive and hazardous), and sanitary wastes. After a waste is generated and tested to identify its characteristics (and therefore its management requirements), the waste is stored awaiting treatment or disposal. The waste management practices used depend on the type of waste. DOE is working to provide adequate, permitted

storage facilities for existing waste while developing treatment and disposal facilities for future wastes.

The Waste Management Program's storage-related responsibilities include resolving safety concerns; ensuring that adequate waste characterization data exist to support treatment, storage, and disposal activities; preparing, packaging, and transporting waste for storage; constructing and operating facilities; and providing technical support to ensure that regulatory requirements are met.

In the treatment of wastes, the Department faces many challenges, some of which require the development of new technologies. Treatment strategies can include changing the waste form (for example, changing a solid to a more safely and easily handled liquid), changing the characteristics of the waste through chemical or other treatments, and reducing the volume of waste by compacting, incinerating, evaporating, or recycling it, or by other appropriate means.

Disposal options are designed to permanently isolate waste from the environment. Disposal activities include packaging and transporting waste to departmental facilities and constructing and operating disposal facilities. DOE is developing disposal facilities and using commercial facilities where appropriate. Because the treatment, storage, and disposal requirements vary according to the type of waste, this section describes management practices and progress made during 1992 and 1993 by waste type.

Radioactive Waste

As a result of many years of defense operations, DOE has very large quantities of radioactive wastes. These wastes are categorized as high-level, transuranic, low-level, or mixed. They vary in physical form, level of radioactivity, and longevity of their radioisotopes. The combination of these factors and the waste source determine the management requirements for the waste.

High-Level Waste

The treatment of DOE-generated radioactive wastes involves preparing the wastes for safe storage and disposal. Treatment approaches can include solidifying, evaporating, or removing some waste components by chemical processes or other methods. For some high-activity waste, storage may enable radioactivity levels to be reduced by radioactive decay, thereby making treatment and disposal less hazardous.

High-level wastes are currently being stored pending treatment to produce a safer, more stable and more easily managed waste form. Once it has treated the waste, EM plans to dispose of high-level and high-level mixed waste in a deep-mined geologic repository. The Department is now characterizing Yucca Mountain in Nevada to determine whether it would be a suitable repository for spent nuclear fuel and high-level mixed waste.

At DOE's Idaho National Engineering Laboratory and the Hanford and Savannah River facilities, DOE stores high-level liquid waste in underground steel tanks. These tanks have combinations of liquid, salt from evaporation, and sludge from solids precipitation. For high-level wastes, three Department facilities—the Defense Waste Processing Facility (Figure 10-1) at the Savannah River Site in Aiken, South Carolina; the West Valley Demonstration Project in West Valley, New York; and the proposed Hanford Waste Vitrification Plant in Richland, Washington—are planning to use a solidification process called vitrification to immobilize the high-level radioactive waste in a borosilicate glass form.

The Savannah River site stores more than 33 million gallons (125 million liters) of high-level radioactive waste in large steel tanks. The site has projects under way to remove the waste for processing in the Defense Waste Processing Facility. The site uses three evaporators to reduce the volume of high-level liquid radioactive waste. The remaining concentrated waste will be used as feedstock for the Defense Waste Processing Facility.

In 1992, testing at the experimental facilities built to support the Defense Waste Processing Facility showed a number of technology issues needed to be resolved before beginning the cold chemical runs. To address the technology issues, the Department commissioned an independent process technology review team to evaluate the proposed approach. In addition, a separate team evaluated the facility's startup schedule to ensure that it accounted for all the necessary activities and was sufficiently aggressive to achieve startup on time.

In 1993, the Defense Waste Processing Facility received authorization to begin cold chemical runs. These began on March 8, 1993, but were suspended on April 5, 1993, after a testing incident in which water entered the melter. An investigation indicated that the discipline of operations at the facility needed to be improved and that hardware modifications were needed. Once the melter was dried out, it was restored to a ready condition. Cold chemical run testing resumed in July. The late wash facility will further pretreat one of the two waste streams the Defense Waste Processing Facility will vitrify. The Department is

10-1. The Defense Waste Processing Facility at Savannah River. Radioactive sludge is dissolved in molten borosilicate glass and poured into stainless steel canisters. A plug is fused to the canister opening, which creates a seal that is stronger than the canister itself. DOE plans to construct a similar facility for the Hanford Site in Washington State.

evaluating a new schedule for the start of radioactive operations.

Major accomplishments at the Idaho National Engineering Laboratory in 1992 included the processing of more than 250,000 gallons (940,000 liters) of high-level liquid waste into a more stable solid granular form known as calcine (see Figure 10-2) and the startup of the Liquid Effluent Treatment and Disposal Facility, which will fulfill DOE's commitment to remove trace radionuclides from wastewater disposed of through unlined percolation ponds at the Idaho Chemical Processing Plant.

The West Valley Demonstration Project continued to make significant progress in 1992 and 1993. The first of as many as four sludge-wash operations, in which the high-level waste sludge is washed with water to remove salts, began on schedule in October 1991 and was completed in March 1992. The wash water continues to be processed in

10-2. The New Waste Calcining Facility at the Idaho National Engineering Laboratory, which converts high-level waste into calcine. Liquid waste droplets contact hot particles in the fluidized bed and solidify onto them. The granular end product is transported through pipes to stainless steel bins. The bins, which have a lifespan of hundreds of years, are encased in underground concrete vaults.

the Integrated Radwaste Treatment System, and the resulting concentrated low-level waste is being incorporated into a cemented waste form that is put in retrievable storage onsite. In August 1993, West Valley filled 15,000 drums with cemented low-level waste from supernatant and sludge wash liquid.

The last mechanical-electrical contract for West Valley's high-level waste vitrification facility was awarded in late 1991; construction of the facility should be completed in 1994. Vitrification radioactive operations should begin on schedule in 1996. Preparation of the draft environmental impact statement for project completion and site closure is under way.

In 1992 and 1993, management of the 61 million gallons (231 million liters) of highly radioactive waste stored in tanks at the Hanford site continued to be one of the most complex and challenging legacies of the cold war (see Figure 10-3). The strategy for managing these wastes has evolved through engineering and environmental studies and agreements with the regulators.

DOE established the original strategy for managing the tank wastes in 1987, when the *Management and Disposal of High-Level, Transuranic and Tank Waste, Hanford Site Final Environmental Impact Statement* was issued. A

record of decision followed in 1988. Key provisions of the environmental impact statement and record of decision were incorporated into the Hanford Federal Facility Agreement and Consent Order (or Tri-Party Agreement), which was signed in 1989 by the Department, the Environmental Protection Agency's Region 10, and the Washington State Department of Ecology. For 10 high-level double-shell tanks, this agreement contained milestones for pretreating the waste onsite using the existing B-Plant,

10-3. Double-shell tanks at the Hanford site. The tanks incorporate improved leak-detection systems and waste confinement features that replace old single-shell tanks.

then vitrifying it onsite in the Hanford Waste Vitrification Plant, which Hanford would build for that purpose. The Department would then immobilize waste from the remaining 18 double-shell tanks onsite, without pretreatment, in grout. The Tri-Party Agreement did not address how DOE would dispose of single-shell tank waste.

After independent engineering reviews in 1991, the Department recognized that significant changes had occurred in the tanks situation since the Tri-Party Agreement had been signed, including:

1. The identification of significant, previously unknown safety issues
2. The continued degradation of tank farm facilities and equipment, which made it much harder for Hanford to safely store tank wastes
3. The determination that several existing facilities could not be used to process wastes because they did not meet regulatory requirements
4. The adoption of retrieval and treatment of waste from the 149 single-shell tanks as a planning base, which greatly increases the volume of waste to be treated as well as the complexity of required waste treatment
5. The identification of potential performance issues related to the grouting of untreated tank wastes

In December 1991, DOE reached agreement with the Environmental Protection Agency and Washington State Department of Ecology to embark on a 15-month rebaselining of the tank remediation to provide integrated management of the characterization, retrieval, pretreatment, safe storage, maintenance, and eventual disposal of all of the highly radioactive tank waste at Hanford. The rebaselining effort provided a systematic reevaluation of the existing waste remediation strategy and an evaluation of alternative strategies and technologies that would provide the best technical solution to the Hanford tank waste problems. At the completion of the rebaselining effort in March 1993, the Department proposed a modified tank waste remediation strategy that included several key features, including:

1. Accelerated resolution of safety issues associated with storage of the wastes
2. Upgrading of tank farms and supporting infrastructure
3. Acceleration and refocusing of waste characterization efforts on data required for resolution of safety issues and retrieval and processing of tank wastes

4. Accelerated cleanup and disposal of liquid tank wastes using available technologies
5. Parallel technology development for advanced separation and high-capacity vitrification of the greatly increased volume of sludges resulting from retrieval of waste from all 177 tanks, with selection of the preferred technical approach in 3 to 5 years
6. Delayed design and construction of a Hanford vitrification facility pending selection of the technical approach for sludges
7. Continued evolution of the tank remediation program through use of systems engineering and stakeholder participation

Based on this strategy, the Department proposed changes to the Hanford Tri-Party Agreement in a number of areas, including grouting of double-shell tank wastes, pretreatment of double-shell tank wastes, construction of the Hanford Waste Vitrification Plant, characterization of single-shell tank wastes, and demonstration of retrieval methods for single-shell tank wastes. In March 1993, the three parties to the Tri-Party Agreement jointly agreed to a 6-month renegotiation period. The renegotiation period allowed for examination of DOE's proposed technical strategy against alternative proposals for cleaning up the Hanford site, consultation with the public, and the conclusion of negotiations on a reasonable course of action for remediating Hanford tank wastes. The three parties also agreed to postpone for 6 months the start of construction and hot startup of the Hanford Waste Vitrification Facility. All other Tri-Party Agreement milestones remained in effect during the renegotiation period; DOE promised to continue to support the existing milestones unless and until changes were negotiated.

During the renegotiation period, the Department continued efforts to resolve the high-priority tank safety issues and to make tank farm operations more productive and efficient. In August 1993, the Hanford site management and operating contractor, Westinghouse Hanford Company, responded to several safety incidents by halting all tank farm activities except those specifically required by operational safety requirements, Tri-Party Agreement milestones, or other regulatory commitments. None of the halted operations will start up again until a "safety culture" has been established and the conduct of operations has been upgraded to an acceptable level. In September 1993, the Department announced a safety initiative that focused management and technical resources on accelerating the elimination of safety hazards and risks posed by the tank wastes. During 1993 the Department

also established the tank remediation as a single major system acquisition and reorganized the contractor and DOE Headquarters and field Tank Waste Remediation System organizations to enhance tank remediation management at all levels.

The Tank Waste Remediation System Program faces many challenges. Recent activities have focused on resolving safety issues while setting a clear, well-defined strategy for the comprehensive cleanup of Hanford tank wastes. The development of a sound technical strategy through systems engineering and stakeholder participation holds great promise for integrating the many technical, safety, infrastructure, and management aspects of the Hanford site cleanup. The Tri-Party Agreement of 1994 set the course for successfully managing and disposing of the tank waste at the Hanford site.

DOE-Owned Spent Nuclear Fuel

Recent DOE decisions and changing conditions throughout the world have both increased demands on the Department with respect to managing spent nuclear fuel. In 1992, DOE decided to phase out the reprocessing of spent nuclear fuel from DOE production reactors. This decision has led to increased inventories of spent nuclear fuel. These inventories have grown further as a result of fuel received from DOE and university research reactors and the Naval Propulsion Reactor Program.

In 1993, the Office of Waste Operations established a new office to bring into focus and resolve the spent nuclear fuel issues challenging the Department. This office is tasked with preparing an integrated, long-term spent nuclear fuel management program to ensure safe interim storage of all DOE-owned spent fuel before the Department permanently disposes it in a mined, geologic repository.

DOE has developed a complexwide spent nuclear fuel policy with input from stakeholder organizations and has begun detailed planning and has analyzed the environment at various sites, assessed fuels and facilities, and developed options for storing the spent fuel. The development of an environmental review of the complexwide spent nuclear fuel program, as required under the National Environmental Policy Act, was integrated into the environmental impact statement being prepared for the Idaho National Engineering Laboratory.

Additionally, DOE stepped up efforts to review its policy for receipt of foreign research reactor spent nuclear fuel of U.S. origin. The Office of Environmental Management prepared and disseminated for comment an environmental assessment evaluating the initial receipt of 550 fuel

assemblies in support of a decision to be made at the end of 1993. Planning for development of an environmental impact statement and evaluation of the return of the remaining foreign research reactor fuel was also initiated.

The Department is working to establish program requirements and an integrated program plan among the various sites. DOE will create a national technology development plan to identify and develop treatment alternatives to meet the requirements specified in a performance assessment of spent nuclear fuel and various types of repositories.

Transuranic Waste

Remote- and contact-handled wastes are stored in retrievable earth-covered trenches and vaults (Figure 10-4). Contact-handled transuranic waste is also stored in stacked drums or boxes on large asphalt and concrete pads or in enclosed facilities, as is done at the Los Alamos National Laboratory. Approximately 2 percent of the transuranic waste is remotely handled (when the waste container has a surface dose rate greater than 200 millirems (2 millisieverts) per hour). Remote-handled transuranic waste requires special radiation protection for waste management workers. Most of the transuranic waste can be safely contact-handled in transuranic waste containers without special protective clothing. Deep geologic disposal is being investigated for most of the Department's transuranic waste.

The Waste Isolation Pilot Plant (WIPP) in New Mexico (Figure 10-5) is a research and development facility designed to demonstrate the safe disposal of defense-related transuranic waste. WIPP is located 26 miles (42 kilometers) east of Carlsbad in Eddy County. The site covers 10,240 acres (4,144 hectares) of Federal land within a 4-square-mile (10-square-kilometer) area. The repository is located 2,150 feet (655 meters) below the surface in a 2,000-foot-thick (610-meter-thick) salt bed with tunnels that extend over 10 linear miles (16 kilometers).

The Waste Isolation Pilot Plant (WIPP) Land Withdrawal Act, Public Law 102-579, was enacted on October 30, 1992. This act permanently transferred the WIPP site and surrounding public lands for sole use by the Department of Energy; established a new regulatory framework involving oversight by seven Federal agencies; defined oversight roles and responsibilities for WIPP oversight groups; established a statutory process for demonstrating compliance with environmental regulations; and placed numerous requirements for the start and conduct of the test, disposal, and decommissioning phases. Passage of the act was the result of intense negotiations between House and

Senate members, the Department, and a number of advocacy groups.

Since the 1980s, waste tests at WIPP had been proposed to support a compliance determination. Since enactment of the WIPP Land Withdrawal Act, DOE and other Federal agencies have been working toward completion of

statutory prerequisites to begin a test phase at WIPP using a limited amount of transuranic waste as part of the compliance strategy. In response to the longstanding concerns of oversight and review groups regarding this strategy (including the National Academy of Sciences and the Environmental Protection Agency), DOE reevaluated and revised its proposed compliance strategy. In October 1993, DOE announced a revised test strategy that includes enhanced laboratory testing of both real and simulated waste in lieu of waste tests at WIPP. The new strategy focuses activities on development of the DOE application for Environmental Protection Agency and State of New Mexico certification of WIPP's compliance with disposal regulations. The WIPP program is implementing this strategy by initiating:

1. An accelerated compliance process and enhanced laboratory program that in 1994 will evaluate and select locations and determine the amount and makeup of waste to be used in the experiments

10-4. A transuranic waste storage site featuring earth-covered trenches and vaults. At some sites, metal drums and boxes containing transuranic waste are stored on asphalt pads in trenches; the containers are enclosed in a protective vinyl cover and backfilled with soil.

10-5. The Waste Isolation Pilot Plant in New Mexico, and a schematic (artist's concept; not to scale).

2. Preparation of a draft compliance package, including a draft determination of compliance with long-term disposal regulations, a draft No Migration Variance Petition, and a draft Resource Conservation and Recovery Act Part B permit application

Activities related to WIPP for 1992 and 1993, and continuing during 1994, include the preparation of documents for transmittal to Congress, oversight groups, and the public, such as:

1. The Land Management Plan, which describes DOE plans for use and control of the land surrounding WIPP until the end of the decommissioning phase
2. The WIPP Strategic Plan, which provides an overview of the objectives, issues, and strategies that impact a decision on the suitability of the WIPP as a permanent disposal facility for transuranic wastes
3. The annual Performance Assessment Update, which summarizes the current status of the data and analysis of the long-term behavior of the repository
4. A Transportation Emergency Response Training Report, which describes the specialized training program that DOE has developed and provided to emergency response personnel along designated WIPP waste transportation routes to ensure that qualified individuals have the knowledge and skill to properly assess the impact of potential transportation accidents and to provide protection to the public and the environment
5. The annual No Migration Determination Compliance Report to EPA for review and acceptance

In addition, DOE continued during 1992 and 1993 to work with the various regulatory agencies responsible for WIPP oversight, completing activities such as:

1. Review of emergency response training by the Occupational Safety and Health Administration
2. Review of the underground opening stability by the Mine Safety and Health Administration
3. Review and certification of the quality assurance program for the contact-handled waste transportation container, the TRUPACT-II, from the Nuclear Regulatory Commission
4. Technical exchanges with the Environmental Protection Agency
5. Transportation and emergency response exercises with state, tribal, and local governments

Finally, the WIPP program continued to strive for operational excellence as evidenced by an exceptional safety record and the safe use of the TRUPACT-II container for the first time to ship transuranic waste between the Idaho National Engineering Laboratory and Argonne National Laboratory-West.

Mixed Waste

Managing mixed waste presents a unique challenge because this waste may contain a combination of hazardous and radioactive components that may be either high-level, transuranic, or low-level, according to DOE definitions. Before DOE can dispose of mixed waste, it must adhere to the Resource Conservation and Recovery Act's (RCRA) Land Disposal Restrictions. These restrictions require DOE to treat hazardous and mixed waste in a way that either eliminates the waste or converts it into a waste form suitable for disposal. These restrictions also require specific treatment standards for a number of unique DOE waste streams; but the Department does plan to dispose of mixed waste in permitted facilities once it has converted the waste into an acceptable form.

In the fall of 1992, Congress passed the Federal Facilities Compliance Act (FFCA). This act directs DOE to negotiate Federal facilities compliance agreements concerning the treatment of mixed waste with states that have DOE sites. The FFCA also directs DOE to develop plans for mixed waste treatment technologies for each DOE mixed waste facility. There are now 50 DOE sites managing radioactive mixed waste covered by the act in 22 states.

DOE has established a task force to manage the activities necessary to meet the requirements of the FFCA. The task force is involved in identifying, collecting, and preparing site treatment reports required by the FFCA. The principal activities for which the responsible are preparing the *Annual Mixed Waste Inventory Report*, the *Annual Progress Report to Congress*, and the *Annual Chief Financial Officer's Report*; interfacing with the Government Accounting Office; and developing site treatment plans for each of the 50 affected DOE sites.

To accomplish the goals and objectives of the FFCA, DOE is working closely with the National Governors Association, the National Association of Attorneys General, tribal governments, and other stakeholder groups to identify cross-cutting issues and resolve issues of equity between the states.

Meetings of DOE and state government representatives, held under the auspices of a National Governors Association cooperative agreement, took place on December

10–11, 1992, in Denver, Colorado, and on May 11–14, 1993, in Salt Lake City, Utah. The next meetings are scheduled for September 23–24, 1993, in Albuquerque, New Mexico.

In 1993, DOE published the *U.S. Department of Energy Interim Mixed Waste Inventory Report: Waste Streams, Treatment Capacities and Technologies*. Publishing the report was the first step in developing the site treatment plans, which are scheduled to be completed by the spring of 1995. A revised inventory report is scheduled for completion in December 1993; the report will be updated annually thereafter.

The FFCAct provides the Department with an opportunity to work more closely with state and Federal regulators on long-range plans for managing DOE waste. Through this effort, DOE will begin to develop the policies under which it will manage and dispose of its existing stored mixed waste, mixed waste it generated in environmental cleanup operations, and any mixed waste it generates in the future.

Low-Level Waste

DOE activities generally dispose of low-level radioactive waste at selected sites in land disposal units. Before disposal, DOE packages and tests the wastes to ensure that they meet disposal requirements established by Congress and the Nuclear Regulatory Commission (Figure 10–6). During the past 10 years, 3.5 million cubic feet (approximately 100,000 cubic meters) of low-level wastes have been disposed of per year. The Argonne National Laboratory-East disposed of 15,191 cubic feet (430 cubic meters) of accumulated low-level waste at Hanford. The Princeton Plasma Physics Laboratory shipped 630 cubic feet (18 cubic meters) of low-level radioactive waste and 125,174 pounds (56,778 kilograms) of hazardous waste for disposal at Hanford. The Fermi National Accelerator Laboratory shipped 2,578 cubic feet (73 cubic meters) of low-level radioactive waste for disposal at Hanford. As part of the Department's waste storage strategy, the Brookhaven National Laboratory began construction in calendar year 1994.

At Savannah River, construction of the low-level radioactive waste disposal facilities is nearly complete. The operational readiness reviews and preparations are progressing on the below-grade concrete vaults, and construction has begun on the Consolidated Incineration Facility. The Consolidated Incineration Facility will treat low-level radioactive, mixed, and hazardous waste in solid or liquid form. Two effluent treatment facilities at the Savannah

10–6. Shallow land burial of low-level radioactive waste in dry areas. When all available space in the trenches is used, earth and a protective covering for erosion control will be placed on top of the waste containers.

River Site continue to treat low-level radioactive liquid waste from processing operations. These facilities treat process wastewater to comply with Clean Water Act requirements for discharges into local surface waters.

The Department has continued, pursuant to the mandate in the Low-Level Radioactive Waste Policy Act (as amended by Public Law 99–240), to provide technical assistance to the states and regional compacts in their efforts to establish new low-level waste disposal facilities. Despite much progress in the technical programs associated with these efforts, resistance to the siting and licensing of these facilities has continued. As a result, many generators are planning on the likelihood of extended onsite storage. Consequently, some of DOE's technical assistance has been in areas relating to mid- and long-term storage.

DOE is responsible for safely disposing of certain low-level waste generated by licensees of the Nuclear Regulatory Commission and its agreement states. This low-level waste contains concentrations of radionuclides that exceed limits established in the Code of Federal Regulations (10 CFR Part 61) and is therefore classified as Greater-Than-Class-C low-level waste. The Department has not selected preferred treatment and disposal methods for these wastes, or similar wastes generated in DOE programs. One category of DOE-generated waste is an exception: The preferred treatment and disposal options have been selected for defense transuranic waste. The Department began technical and economical evaluations of candidate disposal options for the principal types of Greater-Than-Class-C low-level waste in 1992 and continued in 1993.

DOE is improving the efficiency of its waste management by minimizing and properly segregating wastes and by characterizing them better. The Department is also developing improved treatment methods for reducing waste volumes and stabilizing wastes into safer forms that are easier to manage.

Hazardous Waste

The Waste Management Hazardous Waste Program addresses wastes that are identified as hazardous or requiring regulatory control as specified by the Resource Conservation and Recovery Act and the Toxic Substances Control Act. These regulations impose strict controls on the treatment, storage, and disposal of hazardous wastes, and also contain specific permitting requirements for hazardous waste management facilities. The Hazardous Waste Program is designed to comply with these regulatory requirements, reduce risks to human health and the environment, and minimize waste generation. A long-range plan for managing hazardous waste is being prepared for release during the next year.

DOE's hazardous waste management strategy focuses on the use of permitted commercial facilities to treat and dispose of hazardous wastes generated by DOE. Most hazardous waste is stored in RCRA-permitted facilities until it can be shipped to permitted commercial facilities for treatment and disposal (Figure 10-7). Between 1984 and 1991, DOE shipped an estimated average of 13 million kilograms per year of hazardous waste to offsite commercial waste management facilities. In 1992 and 1993, the focus of hazardous waste operations was on complying with regulatory requirements and providing adequate storage capacity for waste. In the past year, DOE made progress

10-7. Hazardous waste packaged in drums and stored on concrete pads awaiting treatment and disposal.

in many hazardous waste-related areas. Many sites have improved their existing facilities or built new facilities for storing hazardous waste in order to meet RCRA requirements.

The Hazardous Waste Program will also continue to improve DOE's ability to properly characterize and package hazardous waste and minimize the amount DOE generates. Specific activities that will improve hazardous waste management include the following:

1. Improving procedures for offsite waste release to ensure that only wastes properly determined as hazardous are shipped offsite to waste management facilities
2. Investigating the establishment of uniform procedures for characterizing waste to ensure that waste

is consistently and properly characterized throughout the Department

3. Investigating the feasibility of a departmentwide Hazardous Materials Exchange Program

From at least as early as 1980 through 1991, some DOE facilities shipped hazardous waste containing extremely low levels of radioactivity to commercial treatment, storage, and disposal facilities. At the time, DOE-funded installations developed their own standards for defining these wastes as nonradioactive. On May 17, 1991, DOE responded to concerns regarding these practices by imposing a moratorium on offsite shipment of all hazardous wastes originating from radiation control areas in DOE installations. DOE is now intensively investigating these waste shipment practices.

DOE studies and independent studies both indicate that these shipments have not created any health or environmental hazards. An independent study conducted by Louisiana State University concluded that incinerating these DOE wastes could result in a maximum radiation dose to the public of 0.1 millirem per year. By way of comparison, the average dose to a person in the United States from background radiation and medical exposures is about 300 millirems per year. A Louisiana Department of Environmental Quality analysis showed that air emissions released while incinerating the DOE wastes would have been within state air emission limits.

To further investigate the waste shipment issues, DOE is reviewing records at four Martin Marietta-operated sites and is auditing six other sites. Preliminary reviews indicate that the shipments contained only extremely low levels of radioactivity, and that they complied with site-specific departmental standards. DOE has formally notified the commercial treatment, storage, and disposal facilities and the associated regulators of the potential radioactivity of the shipments. DOE expects to complete the reviews in early 1994. In addition to the DOE reviews, the DOE Inspector General, several state attorneys general, a Federal grand jury, congressional committees, and others are all conducting their own investigations. DOE has worked as quickly as possible to respond to their inquiries and to work cooperatively with regulators to research and assess the issues.

DOE is focusing on the site-specific standards and procedures that have been used for waste management and is formally reviewing them to ensure that they provide adequate controls for protecting the health and safety of humans and the environment. The Department has also instituted consistent national criteria for unrestricted release

of waste from radiation control areas. These measures should make all DOE waste management practices much more efficient and consistent among the operations offices.

Sanitary Waste

There are essentially two types of sanitary wastes: solid sanitary waste and liquid sanitary waste. The sanitary waste category includes materials that are not hazardous or radioactive.

Solid sanitary waste is routinely generated by normal housekeeping or construction activities (that is, garbage or rubble usually disposed of in sanitary landfills). Solid sanitary waste is disposed of in onsite sanitary landfills owned and operated by DOE or shipped offsite to municipal landfills for disposal. The Office of Environmental Management is responsible for the operation of DOE-owned landfills.

Liquid sanitary waste includes sewage wastewater and industrial wastewater. Liquid sanitary waste may undergo a wastewater treatment process before it is discharged to a publicly owned treatment works or surface waters. Industrial and sewage wastewater is usually treated at onsite treatment facilities or by agreement at municipally owned facilities. Industrial wastewater undergoes pretreatment and treatment processes before being discharged.

Recent progress and plans for the future include the following:

1. The Idaho National Engineering Laboratory will begin building a sanitary waste transfer station that will allow it to dispose of its sanitary waste in a local municipal landfill. This activity will provide the liaison between the Laboratory and the local county for the disposal of sanitary solid waste and will comply with RCRA, Subtitle D.
2. The Argonne National Laboratory-East completed the preliminary design of a laboratory wastewater treatment plant and the final design for laboratory and sanitary sewer collection system rehabilitation.
3. The Oak Ridge K-25 site has been planning the upgrade of sanitary and other wastewater collection systems to comply with the National Pollutant Discharge Elimination System.
4. The Nevada Test Site has completed the upgrade of several sewage lagoons to meet state and Federal clean water regulations.

5. The Los Alamos National Laboratory is continuing work on sanitary wastewater system consolidation.

The DOE program office is responsible for managing liquid sanitary waste, with landlord responsibilities at each individual site. EM is responsible for monitoring DOE liquid sanitary waste management activities to ensure that such operations meet regulatory requirements, and is working with the landlord program offices to evaluate the benefits of taking responsibility for constructing and operating the sanitary sewage systems at locations where it does not already bear that responsibility as landlord. EM is developing a comprehensive strategic plan with specific goals for improving DOE's management of its sanitary waste.

Waste Minimization and Pollution Prevention

Waste minimization and pollution prevention have become high priorities at DOE. The Secretary has assigned the Assistant Secretary for Environmental Management the task of coordinating a departmentwide waste minimization and pollution prevention program. The Assistant Secretary chairs the Department's Waste Minimization and Pollution Prevention Executive Board, which met only once during the reporting period.

Several actions are under way that will increase the visibility of DOE's Waste Minimization and Pollution Prevention Program. The *Waste Minimization Crosscut Plan* and the *Annual Report to the Secretary on Waste Generation and Waste Minimization Progress*, both issued in late 1993, are the key documents that establish the Department's policy to generate less waste.

DOE continues to research, develop, demonstrate, test, and evaluate promising new technologies for minimizing waste and advanced manufacturing technologies with waste minimization design and process features.

Corrective Activities

Corrective activities help DOE's active and standby facilities to expeditiously comply with applicable DOE, Federal, state, and local environmental requirements. These activities are expected to be phased into the program's waste operations budget by the end of 1996 for those activities that require long-term actions to correct the iden-

tified problems. Maintaining such compliance will be the continuing responsibility of operating programs.

Air

To comply with the Clean Air Act and the much stricter Clean Air Act Amendments of 1990, corrective activities are designed to reduce or eliminate unacceptable releases of contaminants to the atmosphere from regulated sources, such as stacks and exhaust vents. The applicable requirements address performance monitoring and evaluation and the design of filtration systems, air scrubbers, and ventilation systems. DOE has been working to improve regulatory compliance and reduce air pollutant emissions for the past 15 years.

In 1992, Sandia National Laboratories-Albuquerque completed an assessment of air emissions. The Nevada Test Site completed a calibration study of nonradiological quality. Rocky Flats expects a National Emissions Standards for Hazardous Air Pollutants compliance determination from EPA following the completion of all requirements in an EPA administrative compliance order. The Lawrence Berkeley Laboratory installed equipment to measure airborne releases.

Water

Corrective activities for effluents strive to reduce or eliminate unacceptable discharges of contaminants to surface waters or underground aquifers, such as those regulated under the Clean Water Act through the National Pollutant Discharge Elimination System. The Department aims to ensure that all pollutant discharge points are identified and all discharges controlled. This includes activities associated with installing or making improvements to wastewater treatment facilities; installing, repairing, or upgrading underground pipelines; upgrading spill containment measures; carrying out construction and improvements related to the collection and retention of contaminated runoff water; characterizing streams; establishing or upgrading wastewater sampling and analysis capabilities; and developing effluent or process monitoring systems.

In 1992 and 1993, DOE completed several sewer construction or diversion projects at the Inhalation Toxicology Research Institute, Los Alamos National Laboratory, Sandia National Laboratories-Albuquerque, Argonne National Laboratory-East, Idaho National Engineering Laboratory, Nevada Test Site, Oak Ridge K-25 site, Lawrence Livermore National Laboratory, and the K-Reactor Cooling Tower at Savannah River. Among the projects DOE

completed was a new sanitary wastewater treatment plant at Los Alamos National Laboratory. In addition, numerous small projects progressed into the design stage. Finally, the Kansas City Plant began to build a flood protection wall.

Rocky Flats is renegotiating its National Pollutant Discharge Elimination System permit. This permit is expected to have a much more stringent ammonia standard, which will require extensive changes to the existing sewage treatment plant.

Solid Waste

Corrective activities for solid waste are aimed at bringing into compliance those solid waste management operations that caused or may have caused the contamination of soil and groundwater. Most of the solid waste corrective activities are conducted to comply with the requirements of RCRA, the Toxic Substances Control Act, and the Federal Insecticide, Fungicide, and Rodenticide Act.

In 1992, the Los Alamos National Laboratory replaced 50 transformers filled with polychlorinated biphenyls (PCBs) and installed 2 major aboveground tanks. The Pantex Plant completed its design of the RCRA Waste and Hazardous Waste Staging Facilities and completed the removal of underground storage tanks. In 1993, the Argonne National Laboratory-West fabricated and installed 99 new liners with cathodic protection at the Radioactive Scrap and Waste Facility. The Brookhaven National Laboratory removed 13 of 21 underground storage tanks and completed upgrades on the remaining 8 tanks. The Fermi National Laboratory completed cleanup of 30 leaking underground storage tanks. The Idaho National Engineering Laboratory completed installation of secondary containment on buried waste lines at the Idaho Chemical Processing Plant. Hanford installed 61 RCRA groundwater monitoring wells; submitted RCRA Part B Permit Applications for the 242-A evaporator and the double-shell tanks; and completed waste analysis plans for the single-shell tanks, the 242-A evaporator, the B Plant and its active treatment, storage, and disposal facilities, and the T Plant.

Program Direction

The program direction function within EM includes those activities associated with program and financial management, environmental impact assessments, environmental

monitoring, employee training, health physics support, quality assurance programs, and other technical support activities that pertain to several waste management functions. The Department must comply with an increasing number of Federal and state requirements in waste management, including the Federal Facilities Compliance Act.

To increase monitoring of activities and projects within the purview of the Office of Waste Management, EM has developed the Progress Tracking System. While improvements continue to be made, the system enables program managers to electronically check the performance of an activity or project against preset performance and financial indicators. The inputs are updated monthly to provide continual feedback to Headquarters managers.

In 1993, DOE began efforts to revise DOE Order 5820.2A, "Radioactive Waste Management," which it had issued in September 1988. The revised order will incorporate the changes in DOE organizational structure and mission responsibilities that have occurred since 1988, clarify and strengthen waste management requirements, and reflect the greatly increased emphasis within the Department on protecting worker and public safety and the environment. The new order combines into a single order the waste management requirements for all waste types for which EM is responsible, along with policy and guidance for managing DOE spent nuclear fuel. Technical working groups headed by DOE senior managers and comprising headquarters and field waste management specialists are drafting the new order, which will be published as DOE Order 5820.2B, "Waste Management." The technical working groups completed their initial draft in September 1993; the departmentwide review was expected to begin in early 1994.

As part of establishing a comprehensive, integrated management approach, the Office of Waste Management began preparing management plans, strategic plans, and related documentation. Descriptions of the current management by major waste types (for example, high-level radioactive waste, low-level radioactive waste, transuranic waste, hazardous waste, mixed waste, and sanitary waste) will be complete in 1994, as will draft strategic plans for future management of the waste. To ensure that a cost-effective, cost-conscious program is planned and executed, the office conducted extensive program cost reviews. Finally, to address basic, infrastructure-related issues, the office began to prepare guidance regarding the review and control of cost estimating, handbooks, and other related items.

It is important that the waste management program have adequate financial and management controls. One com-

ponent of financial control is finding ways to cut costs. Benchmarking, a process whereby organizations measure their own products, services, and practices against those of their toughest competitors or recognized industry leaders, has been used by some organizations to improve their operations. Benchmarking also involves developing strategies and an action plan for making needed changes.

Although benchmarking is recognized in both the public and private sectors as a proven tool for reducing costs, it is unclear whether the process could be applied to activities such as those of EM. In June 1993, the Department undertook a "Benchmarking for Cost Improvement" initiative to find out. A report on the initiative describes how the Department conducted its study and relates its findings. The report concludes that benchmarking could significantly improve the Department's operations. It proposes that EM can increase its cost-effectiveness by benchmarking its operations with the best-of-class operations in the private sector and other Federal agencies.

Stakeholders were very much involved in the study. Those same stakeholders will rely on the findings in the study to better understand the problems and will share in the responsibility for ensuring that their proposals are acted upon.

The Office of Waste Management has greatly strengthened the management of all outlay program acquisitions for waste facility construction projects per Office of Management and Budget Circular A-109 and DOE Order 4700.1, "Project Management System." The waste facility construction projects activity includes completion of design, construction, permit, National Environmental Protection Act, acquisition, baseline changes, and startup activities within established project, cost, and schedule baselines. The responsibility and authority for providing oversight and quality assurance and for approving project baselines is clearly established at the appropriate level of DOE line management. The purpose of strengthening the project management system is to ensure the application of sound management principles to provide a disciplined, systematic, and coordinated approach to project management. This should result in efficient planning, organization, coordination, budgeting, oversight, accountability, performance assessment, review, and control of all outlay for waste facility projects.

ENVIRONMENTAL RESTORATION

The goal of environmental restoration is to ensure that risks to human health and safety and to the environment

posed by DOE's past, present, and future operations at its facilities and sites are either eliminated or reduced to prescribed, safe levels. The Environmental Restoration Program assesses and cleans up sites and facilities contaminated with radioactive, hazardous, and mixed waste as a result of past operations connected with DOE nuclear programs. These sites and facilities must be cleaned up to meet Federal, state, and local regulations.

Environmental Restoration consists of two major activities: remedial actions and decontamination and decommissioning. Remedial actions encompass (1) site discovery, preliminary assessment, and site inspection; (2) site characterization, analysis of remediation alternatives, and selection of remedy; (3) remediation and site closure; and (4) site compliance monitoring.

Decontamination and decommissioning is concerned with the safe caretaking of surplus nuclear facilities until their decontamination, followed by entombment, dismantling and removal, or conversion to another nonnuclear use. Decontamination and decommissioning tasks encompass (1) surveillance and maintenance; (2) assessment and characterization; (3) environmental review; (4) engineering design; (5) decontamination and decommissioning operations; (6) waste disposal; and (7) closeout.

Facilities and Sites

The facilities and sites activity conducts assessments, remedial actions, and decontamination and decommissioning projects to reduce and remove the potential risks to the environment and to human health and safety resulting from past DOE activities. Also included are landlord support activities at several DOE sites and compliance oversight expenses for state and external organizations where remediation efforts are being conducted.

The remedial action requirements are derived principally from the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended by the Superfund Amendments and Reauthorization Act of 1986, and RCRA, as amended. The program consists primarily of activities related to remediation of inactive waste disposal sites, uncontrolled release sites, and underground storage tanks. The scopes, schedules, and remediation standards for these activities are negotiated with the Environmental Protection Agency and the affected states and are subject to RCRA permits, consent orders and compliance agreements, and CERCLA Federal facility agreements.

Decontamination and decommissioning activities are carried out in accordance with provisions of the Atomic

Energy Act and requirements set forth in various implementing DOE orders, standards, and other guidance documents. For facilities for which it is determined there have been or there is a potential for releases to the environment, the provisions of CERCLA or RCRA may apply. State requirements also apply in certain instances. Decontamination and decommissioning efforts include such facilities as reactors, hot cells, production facilities, laboratories, processing plants, storage tanks, and other structures that have been contaminated by past Department activities.

Changes to the Environmental Restoration Program planning since the last annual report are the result of (1) new agreements, permits, and orders; (2) placement of certain sites on the EPA National Priorities List; (3) various external reviews of proposed activities; (4) the results of DOE reviews; and (5) incorporation of new sites into the program. The Environmental Restoration Program has made measurable progress at every DOE field site during the past year in site characterization, closure plan preparation, site remediation, and decontamination and decommissioning activities.

At Sandia National Laboratories in New Mexico, an extensive sitewide hydrogeological survey was begun, the closure plan for the Chemical Waste Landfill was approved under requirements of RCRA, and remediation is proceeding for the Chemical Waste Landfill.

At Los Alamos National Laboratory in New Mexico, remediation of a mortar impact area within the Los Alamos town site was completed, and fieldwork for assessment of other sites is proceeding under RCRA requirements.

Agreements-in-Principle

The Department is pursuing agreements-in-principle with states where nuclear explosives were detonated in the past. An agreement-in-principle was signed with the State of Nevada in 1990, and another with the State of Mississippi in January 1991. Agreements are in place with Florida and Texas. Alaska is expected to sign an agreement in principle in 1993, Missouri in 1994, and Colorado and New Mexico in 1995. An agreement with Ohio was signed in 1993.

Remedial Actions

A wide variety of assessments and remedial actions are now being carried out at the various Department sites across the country. In 1992 and 1993, extensive characterization and assessment efforts, under agreements and permits contained in the Comprehensive Environmental Response,

Compensation, and Liability Act of 1980, were conducted at the Los Alamos National Laboratory in New Mexico, the Pantex Plant in Texas, the Pinellas Plant in Florida, and the Kansas City Plant in Missouri. At the Sandia National Laboratories in New Mexico, characterization, assessment and interim remedial actions continued under the New Mexico Water Quality Control Commission Regulations and the Hazardous and Solid Waste Amendments Act permit, respectively. The Department funded its share for the remediation of the South Valley Site in Albuquerque, New Mexico, which is on EPA's National Priorities List and for which DOE is one of several potentially responsible parties. Characterization activities also were conducted at the Argonne-East site under Illinois solid waste regulations, at the Ames Laboratory under Iowa hazardous waste regulations, and at the Princeton Plasma Physics Laboratory in accord with New Jersey hazardous waste regulations. Specific activities at the major Department sites are described below in more detail.

Rocky Flats Office

As part of the Rocky Flats environmental restoration activities, DOE sought to involve local stakeholders in its efforts. The Rocky Flats Plant in Colorado is located upstream of the drinking water supply for the cities of Broomfield, Northglenn, Thornton, Westminster, and Federal Heights. Although there is no imminent threat of contamination, DOE is working with the local communities and the regulatory agencies concerned with the drinking water supplies, thereby opening up a dialogue with the local municipalities and facilitating development of a plan to protect one of the local drinking water reservoirs, the Standley Lake Reservoir. The Department also provided funds to the cities to develop a new water supply to replace the Great Western Reservoir. The cities involved in the Standley Lake Protection Project decided to drop the diversion canal from the project because of local neighborhood opposition to the canal's close proximity and because of Endangered Species Act constraints regarding a bald eagle nesting site next to the proposed alignment for the canal. Instead, the cities have agreed to build an offsite holding reservoir above Standley Lake with a pump station and pipeline to eventually transfer water to the Great Western Reservoir. DOE is also performing onsite activities to manage surface water with the goal of reducing the amount of water leaving the Rocky Flats facility and protecting the surrounding cities' drinking water supplies from contamination.

Cooperative efforts to involve local community groups in the plant's planning process have also begun. The goal

of this activity is a cooperative agreement on issues related to future land use and economic development. By including the local groups in the planning effort, DOE expects to develop a land use strategy that is practical and worthy of local support. The Department and the various stakeholders have established a joint working group that has drafted a methodology for choosing among different scenarios for future land use.

DOE has augmented its systems for intercepting underground drainage and containing contaminated groundwater flowing from the plant and has extensively tested the operational efficiency of the Rocky Flats 881 Hillside French drain system, which intercepts and pumps contaminated groundwater to an onsite treatment system, to ensure that it is running safely and efficiently. The contaminated groundwater collected from the Solar Ponds area by the interceptor trench system has been successfully diverted to the modular tanks. A new evaporation treatment facility dedicated to the Solar Ponds subproject to treat the contaminated groundwater has allowed the Department to stop placing groundwater in the Solar Ponds, and has allowed the plant to begin closing the impoundments. Remediation of the five solar evaporation ponds has progressed. The largest pond impoundment, Pond 207A, has been emptied of sludge and wastewater. The redirection efforts, started to reflect a changing regulatory framework, limited near-term availability of offsite disposal facilities, and technology limitations, have been refined. The Department has developed a plan with the Colorado Department of Health and EPA to speed up the removal and safe storage of the pond sludges. This plan will speed remediation, remove a source of groundwater contamination, and reduce costs. A process to collect and treat surface waters in the 903 Pad, Mound, and East Trenches Area has been started and is effectively removing contaminants from seep water that would otherwise be discharged to Woman Creek and the Standley Lake drainage system. Collectively, the systems have treated more than 20 million gallons (976 million liters) of water.

A preliminary plan has been formulated that defines the scope of the onsite pond water management Interim Measure/Interim Remedial Action and which would serve as the basis for any regulation of the surface water ponds under CERCLA. The Department has submitted a pond water Interim Measure/Interim Remedial Action Decision Document to the regulators for concurrent review.

Remedial Investigation has been completed and feasibility studies started at the 881 Hillside and 903 Pad, Mound, and East Trenches Areas. Remedial investigation is well under way at the remaining operable units outside

the industrial area. Nonintrusive fieldwork for operable units in the industrial area has begun. An Interim Measure/Interim Remedial Action Plan is being developed for the early cleanup of industrial area operable units.

Pantex Plant

Facility investigation work is ongoing at the Pantex Plant near Amarillo, Texas, under a RCRA permit issued by the Texas Natural Resources Conservation Commission (formerly the Texas Water Commission). The commission has so far approved 12 of the 14 RCRA Facility Investigation work plans that DOE has submitted. All 14 of the work plans were provided to the commission by June 1993 as stipulated by the permit. Ten field investigations have been initiated, and of those, phase I investigations at four areas are completed. Recommendations for no further action have been forwarded to the commission for two of those areas, and phase II investigations are required at the other two. The remaining field investigations will begin in 1994.

In August 1993, DOE, the Office of the Governor, and the EPA sponsored a public workshop to introduce the Federal Facilities Environmental Restoration Dialogue Committee's report and exchange ideas on the formation of a site-specific advisory board. Several stakeholders, including members of the Public Information Coordinating Group, asked that such an advisory board be formed. DOE is committed to the establishment of such a board and will continue to support efforts toward its establishment and meaningful involvement in the Department's activities at Pantex.

Mound Plant

In July 1993, the State of Ohio joined the 1990 CERCLA Federal facility agreement between DOE and EPA's Region 5 concerning remediation of the Mound Plant in Ohio. Assessment fieldwork has been completed at Mound for one operable unit, and work for other operable units includes soil gas and geophysical surveys, the installation of piezometers and groundwater wells, sitewide ecological studies, seismic refraction studies, hydrogeological investigations, and background studies. Mound has removed the roof of the Special Metallurgical Building as the first step in the building's dismantlement. Dismantlement will continue in early 1994 once the penthouse is decontaminated. Approximately 210,000 pounds of metal will then be smelted offsite for recycling. In addition, Mound has continued to remove contaminated soil from a leach field adjacent to the Special Metallurgical building.

Idaho National Engineering Laboratory

At the Idaho National Engineering Laboratory Radioactive Waste Management Complex, where transuranic wastes from the Rocky Flats Plant are buried, the Pit 9 comprehensive demonstration/interim action was initiated; the request for proposals was issued, and two subcontractors were selected for a 1-year proof-of-process test. Process testing to validate Pit 9 remediation technologies began in November 1992, and tests are ongoing at offsite contractor facilities in the United States and Great Britain. The Pit 9 draft interim action record of decision (ROD) was completed, submitted to EPA and the Idaho Department of Health and Welfare, and signed by all parties. The Pad A draft proposed plan was also transmitted to EPA and the Idaho Department of Health and Welfare. A geophysical survey, using magnetics and electromagnetics, was completed for the transuranic pits and trenches. Six monitoring wells were installed at the Subsurface Disposal Area, and a study examining methods for extracting organic contamination from the Vadose Zone was successfully completed.

At the remaining Idaho National Engineering Laboratory Waste Area Groups, the regulators completed and signed seven RODs, including RODs for the Test Area North Injection Well Interim Action, the Test Reactor Area Warm Waste Pond Interim Action and Perched Water, the Central Facilities Area Motor Pool Pond, the Power Burst Facility Evaporation Pond Interim Action, the Auxiliary Reactor Area Chemical Pond, and the Miscellaneous Sites Ordnance Areas Interim Action. Remediation of three of the four interim action sites has begun. At Test Area North, 6,000 gallons (22,713 liters) of mixed waste and approximately 250,000 gallons (946,353 liters) of organically or radioactively contaminated water from well drilling and purging were treated using an economical portable water treatment unit. At the Idaho Chemical Processing Plant, two surface radiation remediation projects and characterization of a hexone spill were completed. The regulators have approved 57 release sites as needing no further action, and EM has signed a notice of intent for the sitewide environmental impact statement.

Brookhaven National Laboratory

At the Brookhaven National Laboratory, on Long Island, New York, an interagency agreement between DOE, the State of New York, and EPA has been in place since May 1992. The agreement contains schedules and milestones for several operable units and removal actions. The

laboratory is located over an EPA-designated sole-source aquifer and several priority removals have been identified. One ongoing effort is the Spray Aeration Project, which is designed to remove tritium contamination and reduce the migration of a contaminated groundwater plume. A historical review was completed this year, and the sitewide monitoring program was expanded.

Grand Junction

The Grand Junction Projects Office Remedial Action Project, located in Grand Junction, Colorado, involves the remediation of over 200,000 cubic yards (152,910 cubic meters) of radioactive mill tailings left over from the processing of uranium ore, as well as the decontamination or removal of a number of onsite structures. Approximately 130,000 cubic yards (99,392 cubic meters) of mill tailings and contaminated materials were removed from the site during 1992, with two buildings demolished in the process. The removal of onsite contamination continued during 1993. These restoration activities are being conducted in accordance with a record of decision that was based on a remedial investigation/feasibility study-environmental assessment.

Nevada Test Site

At the Nevada Test Site, EM is conducting an extensive groundwater characterization program at all past underground test areas. Assessment and remediation of a number of industrial waste sites are also being conducted. Remedial investigation/feasibility study activities on surface soils contaminated with plutonium as a result of past testing are also under way, including research and testing of potentially useful technologies for decontaminating large areas. Work was initiated with the State of Nevada on a Federal facility agreement that is expected to be complete in 1994.

Fernald Environmental Management Project

The Fernald Environmental Management Project (FEMP), formerly the Feed Materials Production Center, in Fernald, Ohio, was formally closed on June 23, 1991, following the submittal of the closure package to Congress in February 1991. Although all production operations were discontinued at FEMP in July 1989, formal closure allowed the Department to focus on remediation actions at the site. Education and retraining initiatives at FEMP have con-

tinued and expanded to support the new mission of environmental restoration and waste management at the site.

Negotiations between the Department and EPA began in May 1991 for revision of the FEMP CERCLA consent agreement as a result of three notices of violation issued in December 1990. The amended CERCLA consent agreement that was signed in September 1991 contains new schedules that are based on a well-defined scope of work. Key aspects of the amended consent agreement include an "early warning system" for controversial issues and 11 new removal actions that were selected based upon reduction of potential risk at the site. The list of removal actions has been increased annually in accordance with the terms of the consent agreement, such that a total of 28 removal actions have been included. As of October 1992, the Department had met all amended consent agreement milestones ahead of schedule. In December 1992, EPA disapproved the Operable Unit 2 remedial investigation report because of inadequate data. Consequently, the Department asked for an extension of the resubmittal milestone. EPA denied the extension and notified the Department that it intended to assess stipulated penalties. FEMP then proceeded to resolve the dispute informally, negotiating new schedules, settling on the amount of penalties to be paid, and agreeing to conduct a supplemental environmental project, thus avoiding a formal dispute. In addition, the Department completed negotiations with the State of Ohio concerning an April 5, 1990, contempt of court charge for violations of the 1988 consent decree. The stipulated amendments to the consent decree were signed on January 22, 1993, and contain revised schedules for complying with RCRA.

DOE has separated remedial investigation/feasibility study activities into five operable units at FEMP. The Operable Unit 2 remedial investigation report is due to be submitted to EPA in February of 1994. The Operable Unit 1 remedial investigation report was submitted to EPA 5 days ahead of the amended consent agreement schedule on October 7, 1993. On November 18, 1993, DOE transmitted the revised "Proposed Plan/Environmental Assessment for the Interim Record of Decision for Operable Unit 3" to EPA; approval was received on December 3, 1993. EPA conditionally approved the Operable Unit 4 remedial investigation report on October 6, 1993.

There are currently 28 removal actions completed or ongoing at the Fernald site. The completed removal actions include the stormwater runoff from the waste pit and production areas, the removal and disposal of fly ash piles, the improvement of waste pit area containment, the removal of the pilot plant sump, the removal of the nitric acid tank, the improvement of erosion control and bank

stabilization, the installation of bentonite clay at Silos 1 and 2 to control releases, the removal of the contents of the K-65 Decant Sump, the dismantling and disposal of the Pit 5 Experimental Treatment Facility, and the disposal of the Silo 3 Dust Collector. Ongoing removal actions include the Plant 1 Pad extension and upgrade, the excavation of contaminated soils adjacent to the sewage treatment plant, the mitigation of the South Groundwater Contamination Plume (which included the installation of two interim advanced wastewater treatment facilities), the removal of waste inventories, the removal of the Plant 1 ore silos, the improvement of the management of soil and debris, the control of exposed material in Pits 5 and 6, the Plant 7 dismantling, the stabilization and removal of uranyl nitrate inventories, the removal of asbestos, the decontamination and removal of the fire training facility, safe shutdown activities, and the removal and recycling of approximately 2,200 tons (1,995 metric tons) of contaminated scrap metal, 1,488 tons (1,350 metric tons) of which have been processed into shield blocks.

The Fernald Waste Management Program's accomplishments include the shipment of tributyl phosphate and diamyl phosphinate to the Toxic Substances Control Act incinerator for disposal (bringing the total volume of waste treated to 16,000 gallons, or 60,570 liters); shipment of 294 drums of barium chloride mixed waste debris to the Envirocare disposal facility in Clive, Utah; and shipment of 6,800 drum equivalents of magnesium fluoride to the Nevada Test Site. Overall, the low-level waste inventory was reduced by 84,193 drum equivalents, bringing the year-to-date total for 1993 to 106,417 drum equivalents that were shipped.

On December 1, 1992, the first environmental restoration management contractor (ERMC), the Fernald Environmental Restoration Management Corporation (comprised of Fluor Daniel and its subcontracting team) assumed managerial responsibility for FEMP. The ERMC concept is an innovative contracting strategy that replaces the standard management and operating contractor with contractors that are experienced in remediation. In June 1993, the FEMP ERMC attained a milestone of 1 million hours without a workday lost due to injury.

Oak Ridge Reservation

The Oak Ridge Reservation in Tennessee began remedial actions at the K-25 site, the Y-12 Plant, the Oak Ridge National Laboratory, and sites off the reservation. At the K-25 site, formerly called the Oak Ridge Gaseous Diffusion Plant, the transfer of stabilized sludge drums to RCRA-compliant storage was completed as part of the Pond Waste

Management Project. The K-1070 C/D burial site phase II remedial investigation work plan was submitted to EPA and Tennessee regulators, and the K-25 railroad spur was upgraded, which will allow DOE to transfer items such as UF₆ feed cylinders more economically by rail.

DOE also completed the following activities—some of them offsite projects—at the Oak Ridge Reservation. At the Y-12 Plant, three dense nonaqueous phase liquid monitoring wells were completed. In addition, the Lower East Fork Poplar Creek Site Characterization Summary and Treatability Study Report was completed and presented to the regulators. Upon its completion, the draft feasibility study/environmental impact statement was submitted to Headquarters on September 30, 1993. Sampling and analysis plans were developed for the Clinch River-Watts Bar Reservoir remediation, and an engineering evaluation and cost analysis report was completed for the CSX Railroad site. Removal actions for the David Witherspoon, Inc., site and the Mercury Tank Remediation Project were completed. Shredding and removal of open containers at the Kerr Hollow Quarry has been completed, and vessel breaching operations continue, with the closure to be completed in early 1994. Closure of the Bear Creek Valley walk-in pits and investigation of Roger's Quarry were initiated, and cap construction was completed at the United Nuclear Corporation site.

At the Oak Ridge National Laboratory, DOE submitted a remediation schedule for inactive liquid low-level waste storage tanks to EPA. The interim records of decision for Waste Area Groups 11 and 13 were approved by the regulators. The interim remedial action at Waste Area Group 13 is in progress, and the interim remedial action at Waste Area Group 11 began on schedule in November 1993. Cofferdam construction at White Oak Creek Embayment, interim RCRA closure of the Building 3001 Storage Canal, and excavation, removal, and decontamination of tank 7860A were completed. Three remedial investigations/feasibility studies are in progress at Oak Ridge National Laboratory at Waste Area Groups 1, 5, and 10.

Significant progress has also been made in various Oak Ridge offsite projects, including completion of remedial investigation activities at East Fork Poplar Creek, the CSX Railroad environmental evaluation/cost analysis, and phase I of the Clinch River remedial investigation.

Paducah and Portsmouth Gaseous Diffusion Plants

At the Paducah Gaseous Diffusion Plant in Kentucky, a record of decision for the interim remedial containment of offsite groundwater contamination was approved. The

draft proposed remedial action plan for source control and containment of the North-South Diversion Ditch was developed and submitted for regulatory review. In addition, the draft Paducah Gaseous Diffusion Plant Federal Facility Agreement was developed and is now undergoing regulatory negotiations.

At the Portsmouth Gaseous Diffusion Plant in Ohio, efforts continue on the RCRA facility investigation for quadrants I, II, III, and IV, and on the corrective measures study for quadrants I, II, and III. In addition, closure plans have been completed and approved for eight RCRA solid waste management units.

Weldon Spring Site Remedial Action Project

At the Weldon Spring Site in Missouri, construction and testing of the Quarry Water Treatment Plant and the Chemical Plant Site Water Treatment Plant were completed and operations began. The Waste Materials Staging Area was also completed. Three major demolition contracts were awarded for the Chemical Plant Site buildings and demolition began. Construction of the quarry haul road and the quarry bulk waste temporary storage area was completed, and bulk waste removal operations began. A final feasibility study/environmental impact statement was approved for the Chemical Plant Site, as was the following record of decision for onsite waste disposal.

Kansas City Plant

Extensive assessment work under the RCRA administrative order on consent with EPA's Region 7 is under way at the Kansas City Plant in Missouri. Field work associated with assessment includes soil gas geophysical surveys, the installation of piezometers and groundwater wells, seismic refraction studies, hydrogeological investigations, and other background studies. Groundwater treatment is continuing in the northeast, the trichloroethylene still, and tank farm areas. Removal of polychlorinated biphenyl-contaminated soil from Department 27 Outside was completed in March 1993, while remediation at the Abandoned Indian Creek Outfall is progressing fast and the remediation will be complete in early 1994. Approximately 15,000 tons of contaminated soil were removed through these projects in 1993.

Pinellas Plant

The Pinellas Plant in Florida received approval of its RCRA facility investigation in May 1993. Twelve of the plant's 15 original solid waste management units require no fur-

ther action. Corrective measures studies are under way to determine final cleanup plans for the three remaining site areas. Cleanup of lead-contaminated soil from a former pistol range was completed in February 1993, and interim groundwater remediation is under way to ensure that plumes of contamination remain onsite. One new solid waste management unit was added to the permit; a corrective measures study will begin in 1994. Two additional areas of concern are under investigation to determine whether contaminant releases have occurred, and decisions on further study of these areas are expected in 1994.

Hanford

Four large areas on the Hanford Reservation near Richland, Washington, were placed on EPA's National Priorities List in October 1989. These 4 sites were divided into 78 operable units. All onsite characterization and assessment activities are being conducted under RCRA and CERCLA and in accordance with the Tri-Party Agreement between the Department, EPA, and the Washington State Department of Ecology. Thirty operable units now have characterization and assessment activities. Fourteen of the 19 work plans submitted to the regulators have been approved. Six RCRA closure plans have been submitted to the regulators. Two expedited response actions were completed in 1992 (hexone storage drums and 316-5 process trenches), one was completed in 1993 (sodium dichromate), and eight more are in progress.

A formal change package under the Hanford Tri-Party Agreement was signed by all parties on September 9, 1991, resulting in the implementation of the past practice strategy. This strategy has already reduced costs for the characterization and assessment program. Eleven 100 Area work plans have been rescoped based on the past practice strategy and were resubmitted to EPA and the Washington State Department of Ecology. An agreement in principle with the regulators was signed in September 1993, including plans to accelerate soil and groundwater control or cleanup, decontamination, and decommissioning. In addition, 10 Aggregate Area Management Studies for the 200 Area have been submitted to the regulators. The final remedial investigation/feasibility study report for operable unit 1100-EM-1 was submitted to EPA and the Washington State Department of Ecology in December 1992, completing the Tri-Party Agreement milestone (M-15-01 B/C). An addendum to this document was prepared to permit the record of decision to cover all operable units in the 1100 Area (three additional operable units), thus allowing DOE to take steps to remove one of four Hanford sites from the National Priorities List upon

completion of remediation activities. All 14 Tri-Party Agreement milestones were completed on schedule in 1993. The final environmental impact statement for the decommissioning of eight surplus production reactors at the Hanford site was released.

Savannah River Site

At the Savannah River Site in Aiken, South Carolina, closures of the Metallurgical Laboratory Settling Basin and the 105-C Underground Storage Tank were completed. The A-Area groundwater contamination air stripper was brought online to supplement treatment processes that have already removed 280,000 pounds (127,005 kilograms) of solvent from the groundwater. Negotiations were completed on the Federal facility agreement, which was signed in January 1993 and became effective in August 1993 with the establishment of enforceable milestones. A citizen's advisory board was formed to provide informed recommendations on environmental remediation activities. A Natural Resource Trustee Council has also been formed to address trustee concerns early in the remediation process.

Lawrence Livermore National Laboratory

At the Lawrence Livermore National Laboratory Main Site in Livermore, California, which is on EPA's National Priorities List, remediation of soil and groundwater contamination is being conducted in accordance with a Federal facility agreement. A record of decision for site remediation was finalized in August 1992. Three groundwater treatment facilities have treated more than 55 million gallons (208.2 million liters) of contaminated water to date. At the Lawrence Livermore National Laboratory Site 300, which was placed on the National Priorities List in 1990, two interim groundwater treatment facilities prevent further migration of contaminants offsite in the Eastern and Central General Services Administration areas. The Lawrence Livermore National Laboratory Draft Site 300 Site-Wide Remedial Investigation has been finalized and sent to the regulatory agencies for comment. This document consolidates the assessment and characterization for six operable units at the site.

Lawrence Berkeley Laboratory

At the Lawrence Berkeley Laboratory, located at the University of California at Berkeley, the principal environmental restoration programs involve the assessment of soils, groundwater and the sewer system contamination from

past DOE program activities, the investigation of remedial alternatives, and the restoration of the site to acceptable levels of cleanliness.

Stanford Linear Accelerator Center

At the Stanford Linear Accelerator Center, located on the Stanford University campus and operated by the university under contract to DOE, environmental restoration activities have included the preparation of the draft remedial investigation work plan for PCB-contaminated soil.

Monticello, Utah

The Department's efforts to remediate uranium mill tailings contamination in Monticello, Utah, are covered under a Federal facility agreement that encompasses both the Monticello Remedial Action Project and the Monticello Vicinity Properties Project. Both are on the National Priorities List, and CERCLA records of decision have been issued for each. Remedial action at the processing site began in 1991, as required under CERCLA. The current estimate for restoration work associated with the Monticello Vicinity Properties Project includes a total of 410 vicinity properties. At the end of 1993, 254 vicinity properties had been remediated. Restoration activities for the Monticello Remedial Action Project continued in 1992 with the start of mill site preparation construction and the remediation of two peripheral properties. A work plan for the preparation of the Monticello Surface and Groundwater Remedial Investigation/Feasibility Study was completed in 1992. Site preparation activities at the mill site are continuing.

Decontamination and Decommissioning

Decontamination and decommissioning efforts provide for the safe management and disposition of surplus facilities radioactively contaminated from DOE activities. The Environmental Restoration Decontamination and Decommissioning Program currently includes more than 400 projects at 38 sites in 18 states. These facilities require surveillance and maintenance until decommissioning starts. The Decontamination and Decommissioning Program is expected to include more projects as operating facilities become surplus, are deactivated, and then transferred to the Environmental Restoration Program for remediation.

The Battelle Columbus Laboratory Decommissioning Project in Ohio involves the decontamination and release of 15 buildings at 2 sites that were radioactively contaminated during work conducted by Battelle under contract to DOE. An environmental assessment and a finding of

no significant impact were issued for the project, and decontamination and decommissioning has been completed in 4 of the 15 buildings. Six additional buildings are being decontaminated. The remaining buildings are under surveillance and maintenance. All detailed soil characterization activities at the West Jefferson site in Ohio have been completed. Detailed characterization of the remaining buildings is in progress.

At the Oak Ridge Reservation in Tennessee, shutdown activities at the former Oak Ridge Gaseous Diffusion Plant (now referred to as the K-25 site) dominate the funding allocated for decontamination and decommissioning activities. Significant surveillance and maintenance efforts are also required annually at this facility, which has structures with a floor area exceeding 300 acres (121.4 hectares). Shutdown activities in 1992 included the draining and disposal of 40,000 gallons (151,416 liters) of PCB oils, the removal of more than 1.4 miles (2.25 kilometers) of asbestos insulation, and the disconnection of nearly 10,000 capacitors in the electrical system.

During 1993, the Surveillance and Maintenance Program saved the Department an estimated \$12.6 million by removing and shipping approximately 2.3 million pounds (1,044,200 kilograms) of R-114 liquid coolant to the Paducah and Portsmouth gaseous diffusion plants. In addition, the program developed and submitted Employee Emergency Notification System alternative technology that saved the Department approximately \$4 million. This new technology removed more than 1,113,000 gallons (427,705 liters) of lubricating oil and transferred it to the Toxic Substances Control Act incinerator for disposal, and transferred equipment worth more than \$1.6 million to the DOE operating gaseous diffusion plants.

The Oak Ridge Field Office is responsible for decontaminating, decommissioning, maintaining, and conducting surveillance of surplus facilities at the gaseous diffusion plants in Portsmouth, Ohio, and Paducah, Kentucky; the Oak Ridge Y-12 weapons plant; and the Oak Ridge National Laboratory. All of these installations are providing surveillance and maintenance to surplus facilities as well as a limited amount of facility decommissioning. In the future, the Uranium Enrichment Decontamination and Decommissioning Fund, established by the Energy Policy Act of 1992, will support the decommissioning of the three gaseous diffusion plants at Oak Ridge, Portsmouth, and Paducah.

Decommissioning activities at the Mound Plant, near Dayton, Ohio, are regulated under a Federal facility agreement with EPA's Region 5 and the State of Ohio. Projects include the removal of soil, the Plutonium Processing Building, the Semi-Works Building, the Waste Disposal

Building for underground lines, the Special Metallurgical Complex, and a leach field. Decontamination of the Plutonium Processing Building was completed and is now available for reuse.

In California, major decontamination and decommissioning activities are being conducted at the Laboratory for Energy-Related Health Research at the University of California-Davis, near Sacramento; the Santa Susana Field Laboratory, near Los Angeles; the General Atomics Hot Cell facility, near San Diego; and a hot cell facility at the General Electric Vallecitos Nuclear Center, near Pleasanton. The Laboratory for Energy-Related Health Research is a 15-acre (6.1-hectare) site with five contaminated buildings, underground waste storage tanks, and waste burial trenches. All radioactive source materials have been removed from the site. Decontamination of two animal hospitals was completed during 1993 and sitewide soil and groundwater characterization will begin during 1994. At the Santa Susana Field Laboratory, the lower pond area of the former Sodium Disposal Facility has been remediated, and the rest of the facility is undergoing final surveys. Buildings 059, 005, 064, and 023 have been decontaminated, and final verification certifications are being developed. Decontamination of the Building 020 Hot Cell Facility is continuing. At General Atomics, preparations are under way (phase 1, pre-decontamination and decommissioning) for decontamination of a privately owned hot cell facility leased by DOE for past program activities. At General Electric, Alpha Hot Cell #4 will be decontaminated and returned to the owner for future use. Surveillance and maintenance activities and minor characterization will be performed in 1994.

At the Los Alamos National Laboratory in New Mexico, decommissioning was completed on the Water Boiler Reactor and the Ultra-High Temperature Reactor Experiment facility. At the Idaho National Engineering Laboratory, decontamination and decommissioning of the Army Re-entry Vehicle Facility site, the Special Power Excursion Reactor Test-IV, the Idaho Chemical Processing Plant Chloride Removal System, and the Boiling Water Reactor Experiment-V turbine building were completed. At the Hanford site, decontamination and decommissioning of the 185-B Water Treatment Plant and 190-B Main Pump House was completed in 1993. Other decontamination and decommissioning activities included work at the Argonne National Laboratory in Illinois, which is decontaminating and decommissioning the CP-5 reactor and the Experimental Boiling Water Reactor, the Oak Ridge National Laboratory in Tennessee, and other DOE reservations and remote sites.

Formerly Utilized Sites Remedial Action Project

The Formerly Utilized Sites Remedial Action Project conducts remedial actions at former nuclear processing facilities that became radioactively contaminated as a result of Manhattan Engineering District or Atomic Energy Commission activities and have not been sufficiently decontaminated to meet current public health and safety guidelines. The Formerly Utilized Sites Remedial Action Project also includes certain contaminated sites specifically assigned to DOE by Congress for remedial action.

To remedy the situation at these contaminated sites, either the contaminated materials will be stabilized in place, with restrictions placed on the use of the site, or the contamination will be removed and disposed of elsewhere. The program currently includes 44 sites, of which 39 were formerly used by the Manhattan Engineering District or the Atomic Energy Commission, based on a review of the involvement of these predecessor agencies in previous site activities. The review of sites involved in past activities of the Manhattan Engineering District or the Atomic Energy Commission was completed in 1987; more sites may be added to the project once followup radiological surveys are completed at the sites. Congress added five other sites to the project in 1984 and in 1985.

The general approach to the Formerly Utilized Sites Remedial Action Project is to give priority to the remediation of contaminated residential properties and to store the waste temporarily on each processing and storage site. Federal facility agreements have been negotiated and signed with EPA for six sites, including the Wayne and Maywood sites in New Jersey, as well as the Latty Avenue, St. Louis Airport, site and vicinity properties, and the St. Louis Downtown sites in Missouri. With the completion of the Elza Gate site in Tennessee, the Seymour Specialty Wire site in Connecticut, and the final Baker & Williams warehouse in New York City, remedial actions have been completed at 13 of the 44 sites now under the Formerly Utilized Sites Remedial Action Project. Assessment efforts and preparation of required environmental documents continued at other project sites.

Uranium Mill Tailings Remedial Action Project

The Uranium Mill Tailings Radiation Control Act of 1978 gave DOE responsibility for conducting remedial action at 24 former uranium ore processing sites and several thousand contaminated vicinity properties. In 1992, remedial actions were conducted at 9 processing sites and at 310 vicinity properties. Remedial actions were

completed at the Lowman, Idaho, site, bringing the total number of completed sites to 10. Other sites completed include Canonsburg, Pennsylvania; Durango, Colorado; Green River, Utah; Lakeview, Oregon; Riverton, Wyoming; Salt Lake City, Utah; Shiprock, New Mexico; Spook, Wyoming; and Tuba City, Arizona. Surveillance and maintenance efforts continued at these completed sites. Site remedial action continued at Grand Junction, Colorado, and began or resumed at seven other sites, including Falls City, Texas; Rifle (two sites) and Gunnison, Colorado; Ambrosia Lake, New Mexico; Monument Valley, Arizona; and Mexican Hat, Utah.

In 1993, remedial action continued at the 8 processing sites listed above and was performed at 133 vicinity properties. Remediation was completed at the largest processing site, the Climax Mill Site located in Grand Junction, Colorado, and work on the disposal cell continued. Surveillance, certification, and licensing activities continued for the completed sites and planning continued for the six remaining sites.

Uranium Mill Tailings Groundwater Restoration Project

In 1993, the Uranium Mill Tailings Groundwater Restoration Project began work on the Uranium Mill Tailings Groundwater Programmatic Environmental Impact Statement. Scoping meetings were held in communities near the sites to be restored to obtain public input and present the compliance options being considered. Baseline characterization at some of the sites was begun.

FUTURE DIRECTION

The Environmental Restoration Program has made significant progress over the past year in identifying its needs and setting priorities for the future. In addition to meeting the challenges of existing and anticipated regulatory requirements, the Department is looking to the future by taking actions to facilitate the smooth and efficient operation of the Environmental Management Programs. These include continued development of a programmatic environmental impact statement for all activities under the Environmental Management Programs, development of a centralized data base to facilitate program management and information exchange both within and outside the Department, and innovative contracting mechanisms for remediation work at DOE field installations.

TECHNOLOGY DEVELOPMENT

A critical mission of the Office of Environmental Management (EM) is to research and develop new, improved technologies to clean up the legacy of environmental pollution posed by the 1989 inventory of surplus facilities and to prevent future insult to the environment. For DOE to meet scheduled requirements for remediation and waste management actions, new and innovative technology solutions must be available for consideration *before* remedial actions are begun; that is, during the analysis phase of the remedial investigation-feasibility study process. EM's Office of Technology Development manages an aggressive national program for applied research, development, demonstration, testing, and evaluation (RDDT&E) to transfer usable methods of waste treatment to private industries and DOE user groups.

The RDDT&E programs are organized into the following three major areas:

1. *Groundwater and soils cleanup activities* focus on developing technology systems for the cleanup and containment of hazardous and radioactive contaminants in groundwater and soils. In 1992 and 1993, groundwater and soils cleanup activities focused on technologies and technology systems to characterize contaminated sites and to provide more cost-effective methods for in-situ cleanup of DOE sites. Activities included the evaluation of temporary measures to slow migration or contain radioactive and hazardous material until a suitable cleanup technology has been developed.
2. *Waste retrieval and waste processing activities* center on technologies to retrieve and process hazardous, radioactive, and mixed waste from current DOE weapons complex operations; treat buried and stored wastes; and decontaminate and decommission facilities no longer in operation. In 1992 and 1993, waste retrieval and waste processing activities focused mainly on technologies and technology systems that handle mixed waste residing in drums buried in soil or contained in underground storage tanks. RDDT&E activities to support EM decontamination and decommissioning efforts were also initiated.
3. *Pollution prevention activities* integrate new technologies and technology systems into processes to reduce the toxicity or amount of hazardous or radioactive materials generated at the source and to reduce the toxicity and volume of waste for disposal through recycling, reuse, and treatment.

New Technologies

Among the new technologies developed in 1992 and 1993 are the following:

1. In-situ magnetic separation is being used to remove plutonium from soil. The in-situ process reduces worker exposure during remediation and reduces the volume of wastes requiring final disposal.
2. High energy radio-frequency heating has been demonstrated at the Savannah River Site as a supplement to conventional "pump-and-treat" technologies to enhance the removal of subsurface contaminants. This process greatly reduces exposure to workers and saves energy.
3. Selective leaching of uranium from soil has been demonstrated using carbonate extractions, citric acid extractions, extractions by complex organic chelating agents, and aqueous biphasic extractions. This research has been conducted to reduce the volume of soil requiring disposal at a treatment, storage, and disposal facility. This process also increases the proportion of soil that can be cleaned and returned to its original site, thereby eliminating the need to import clean soil. Tests indicate that these techniques, either alone or in combination, attain extraction rates of 75 percent to 95 percent. These tests have been conducted for the Fernald records of decision (1994-97) and for records of decision at other DOE facilities with uranium-contaminated soils, including Oak Ridge, Paducah, Portsmouth, and Mound.
4. More than 16,000 pounds (7,257 kilograms) of chlorinated organic solvents were removed from soil and groundwater at the Savannah River facility using horizontal wells with in-situ air stripping. This technology greatly reduces the number of wells required for remediating a contaminated area, reduces worker exposure, and performs five times better than vertical wells.
5. Sonic drilling technology that uses a tuned vibrating drill head to place characterization, monitoring, and treatment wells was demonstrated. The sonic drill is three to five times faster than the baseline technology, cable-tool drilling, and does not require the addition of drilling fluids during the process, thereby eliminating secondary wastes normally associated with conventional drilling. The sonic drilling method has been shown to reduce overall costs by 50 percent.
6. A technique called Dynamic Underground Stripping has been demonstrated to clean up hazardous organic compounds spilled from an underground gasoline storage tank at Lawrence Livermore National Laboratory. The process works much like a giant steam cleaner. First, the impermeable clay layers under the ground are heated with an electrical current. Then, steam is injected into the groundwater, stripping away the contaminants, which are then extracted by a vacuum for recycle. Results were dramatically better than those achieved with the baseline approach of pump-and-treat, reducing cleanup time from several decades to 6 months and lowering costs by 75 percent.
7. A heavyweight cone penetrometer has been developed and demonstrated in arid soils. This technology uses a hydraulic ram system mounted on a command truck to push a specially designed probe into the subsurface. As the cone penetrometer is pushed into the ground, onboard sensors and sampling devices allow the instantaneous and continuous collection of characterization data. Typical baseline methods require grab sampling at designated intervals during well placement. The cone penetrometer is suitable for application at more than 2,500 DOE and Department of Defense sites, and it can reduce the cost of site characterization by 60 percent. Its accuracy results from the penetrometer's ability to perform multiple pushes at the same cost as drilling one characterization well by conventional methods.
8. Successfully designed and proved lab- and bench-scale, joule-heated melter tests at 10 and 100 kilograms per day during the minimum additive waste stabilization studies. This process uses multiple waste streams as substitutes for additives otherwise necessary for vitrification to produce a stable, high-quality waste. This technology represents a distinct advantage over conventional treatment because it minimizes the waste volume requiring disposal.
9. Demonstrated Expedited Site Characterization methodology was introduced to environmental practitioners from industry, EPA, DOE, the Departments of Defense and Interior, and state and other governmental agencies. This methodology employs rapid, cost-effective, minimally intrusive technologies for site characterization (remedial investigation-feasibility studies). Technologies include sensor deployment and groundwater-soil gas sampling by cone penetrometer, surface-based geophysical measurements, vegetation sampling, and field analysis

of chemical contaminants. Onsite data analysis, data integration, and decision-making expedite the entire characterization process and have reduced costs by approximately 90 percent compared with conventional characterization of similar sites.

10. A biofilter for the removal of hydrocarbon vapors from off-gas stacks, such as those used for vapor vacuum extraction, was jointly developed through a cooperative research and development agreement between EG&G ROTRON and the Idaho National Engineering Laboratory (INEL). This technology, which employs a vertically stacked series of compost beds, will primarily be used in the remediation of gasoline and fuel spills. A version of the biofilter for use with chlorinated solvents has also been developed and is now in field trials. The use of the biofilter rather than existing destruction techniques could significantly reduce costs and improve regulatory compliance. This technology won a 1993 R&D 100 award (awarded by *Research and Development Magazine*), and has been commercialized by EG&G ROTRON as the "Biocube" for use in conjunction with their high-volume vacuum pumps.
11. Dislodging and conveyance systems were demonstrated for removing waste from underground storage tanks. Several approaches to the removal of soft waste were successfully demonstrated, including high-pressure water nozzles with an air conveyance system that can lift the waste more than 18 meters vertically, which was characterized as "impressive" by the Washington State Department of Ecology. This work was a key step in developing a technology to remove waste from underground storage tanks for treatment.
12. A partnership between Sandia National Laboratories and a small Albuquerque-based firm has developed SEAMIST, an in-situ instrumentation and fluid sampler emplacement technique that improves operations efficiency and reduces costs by eliminating the need for soil sample retrieval for analysis. Potential applications include water sampling below the water table, landfill monitoring, pipe inspection and characterization, and large-scale vapor plume movement experiments and monitoring. This technology has now been commercialized by Eastman Cherrington Environmental Company, Inc.
13. A full-scale demonstration of a Cryogenic Retrieval System was conducted at an Idaho National Engineering Laboratory simulated waste pit. In this demonstration, the contaminated soil was frozen with liquid nitrogen. The frozen waste form was retrieved with remotely operated tools mounted on a bridge crane. Results of this demonstration indicate that cryogenic retrieval is an effective method for freezing contaminated soils and buried wastes. The technology minimizes the spread of contaminated dusts during remediation operations.
14. A Rapid Monitoring Unit was demonstrated to measure loose surface and airborne contamination at a retrieval site. The system is designed to control contaminants at the source of operation by early detection of airborne and loose surface contamination, thereby reducing escape of the contaminants and exposure to the public. The unique feature of this unit is that it provides more rapid and increased sensitivity contaminant detection as compared with conventional techniques.
15. A nitrate-to-ammonia-and-ceramic process was demonstrated to produce an alternative low-level waste form to grout. The process chemically reduces nitrate to ammonia, thereby eliminating the serious threat posed to public health by nitrate in groundwater. At the same time, the product of the chemical reduction can be used to generate a low-level waste form, which reduces the overall waste volume. This process will address the problem of both high- and low-level wastes that contain large quantities of sodium nitrate at DOE facilities, such as the underground storage tanks at Hanford.
16. Pilot-scale testing of a plasma furnace has been completed. The plasma furnace not only destroys organic compounds but also melts mixed waste into solid, stable forms, which will satisfy regulatory compliance issues and provide for safe, cost-effective long-term storage.
17. A Remote Excavation System and Contamination Control Unit was also demonstrated at the Idaho National Engineering Laboratory simulated waste pit. More than 5,000 cubic feet (142 cubic meters) of simulated waste were excavated using a mobile, remote-controlled small emplacement excavator. Currently, workers must wear protective clothing and operate excavation equipment inside the containment structure. The contamination control equipment consists of a self-contained mobile trailer for manual application of fixants, dust suppressants, and misting agents, as well as a subsystem to vacuum loose debris. These technologies will reduce risk to workers and the public by reducing worker exposure and reducing or eliminating the spread of contaminated dust and soils.

18. A Rapid Geophysical Surveyor was designed, demonstrated, and implemented on the Idaho National Engineering Laboratory burial grounds to rapidly and economically collect closely spaced geophysical data for characterization of buried waste. This system was designed to address irregularities identified in surveys. The Rapid Geophysical Surveyor collected data 30 times faster than conventional ground survey techniques, reducing the cost of collecting and processing by 95 percent.
19. A water-jet cutting system device was used to remove hazardous and radioactive portions of weapons components and to segregate wastes during weapons recycling. This system has demonstrated a wide range of capabilities, from simply removing thermal batteries from the preflight control unit to removing the more complex hidden gas tubes.
20. Environmentally conscious manufacturing techniques have been implemented for cleaning, soldering, and monitoring in the manufacturing of three functional demonstration weapon programmers. The aqueous cleaning processes and lead-free soldering techniques eliminate the solvents commonly used in the electronics industry for cleaning flux residue from printed wiring boards. The portable acoustic wave sensor monitoring system improves the ability to control, characterize, and document manufacturing processes, waste streams, and exhaust systems. These techniques could save DOE \$100,000 per year.
21. A nonhazardous solvent, d-limonene, has been used as an alternative cleaning agent in the production of electronic circuit boards. The use of this solvent, which has been successfully integrated into a DOE production and manufacturing process, complies with Federal regulations requiring the elimination of hazardous materials in the workplace.

Cooperative Efforts

The EM Office of Technology Development has actively sought regulatory acceptance of its products and processes. The office has established good relations with Federal, state, and local regulatory agencies and has sought active participation by these organizations in technology development activities. The office has also supported public seminars, training programs, and the establishment of open forums with public organizations and interest groups.

Examples of improved public participation include the following:

1. Endorsement of the interim recommendations of the *Federal Facilities Environmental Restoration Dialogue Committee (Keystone) Interim Report*. EM is now inviting participation by regulatory agencies and input from interested parties in allocating its resources and setting program priorities. In addition, EM is working with state and Federal regulators to establish site-specific advisory boards at several sites to provide public input on remediation and related waste management activities.
2. Establishment of the Hanford Future Site Uses Working Group, which is composed of Federal, state, and local officials; environmental activists; academics; and American Indian tribes. The group recently began to define the future use of the Hanford site by acknowledging that the center of Hanford cannot be fully cleaned up because of resource and technology limitations, and it proposed that certain waste sites be centralized in that area. Its recommendations will be considered in the Hanford Remedial Action Environmental Impact Statement.

The office leverages its resources through interagency agreements, domestic and international agreements, domestic and international public-private partnerships, simplified procurements, and small and disadvantaged business research opportunities to cosponsor RDDT&E activities. These efforts are designed to develop innovative environmental management and restoration technologies and to help EM achieve its goal of cleaning up contaminated DOE and other legislatively authorized sites by the year 2019. These efforts will also provide DOE's private-sector partners with opportunities for regional and local economic growth and improved environmental conditions. Following successful demonstration, testing, and evaluation of advanced or adapted technologies, partnerships help transfer proven environmental management skills and technology to government agencies and private entities facing environmental challenges. Specific activities designed to accomplish technology transfer objectives include small business programs, industrial integration programs, technology seminars, and the International Technology Exchange Program.

The Office of Technology Development now has 17 cooperative research and development agreements in place with private partners to research environmental remediation technologies. In early 1993, the office entered into its first international agreement. The 3-year project, to be carried

out by DOE's Oak Ridge National Laboratory and a German research team, will research developing an environmental remediation technology that uses microorganisms to remove uranium, arsenic, and other metals from waste streams.

Through its activities in 1992 and 1993, the office formed and strengthened alliances with other Federal agencies, national laboratories, private industry, state and local agencies, and universities. The office is working closely with the Departments of Defense and Interior and EPA under a memorandum of understanding signed with the Western Governors' Association in 1991. This alliance was designed "...to establish a more cooperative approach to development of technical solutions to the environmental restoration and waste management problems shared by States, commercial entities, and the Federal government."

The Office of Technology Development also manages crosscutting technical efforts and infrastructure initiatives that support EM and other departmental elements. In 1992 and 1993, crosscutting infrastructure initiatives were conducted in the following areas:

1. Analytical laboratory management provides EM environmental restoration and waste management programs with cost-effective sampling and analysis support to collect the credible environmental data required to comply with Federal facility compliance agreements and other environmental regulations. To accomplish this mission, the analytical laboratory management program is developing and implementing quality assurance programs for sampling and analysis; supporting development of sufficient laboratory capacity to analyze radioactive, hazardous, and mixed waste samples for all EM programs; developing and validating methods for analysis of mixed wastes; and developing an EM-wide information management system for sample management.
2. Robotics technology development provides new technologies, such as state-of-the-art computing and sensor technologies conducted by remote manipulator and vehicle systems. The Robotics Technology Development Program focuses on reducing worker exposure and increasing worker safety by operating equipment remotely, increasing productivity through automation and "intelligent machines," and reducing secondary waste generation by removing workers from hazardous waste areas. For example, a cooperative research and development agreement involving the Pacific Northwest Laboratory and Schilling Development, Inc., is under way to develop robotic manipulators with bet-

ter dexterity than current models. Additional control algorithms will be developed to control oscillations in the movements of long, flexible robotic arms.

3. Decision support provides the overall framework for strategic and tactical risk-based decision-making to help EM make technical and policy decisions that involve large sums of money and have profound technical, economic, social, and political consequences.
4. Emergency management supports the development of a comprehensive approach to plan for, respond to, and mitigate incidents and emergency situations at EM facilities that support EM activities, or for those that occur during nonweapons-related, DOE-wide transportation activities.
5. Liaison and communications facilitates Office of Technology Development outreach activities by providing an effective program for communicating to and interacting with states, local governments, Indian tribes, technical and professional organizations, and the public on technology development activities, with specific emphasis on transportation and emergency management programs.
6. Transportation management develops policies and management procedures to facilitate and coordinate DOE-wide transportation and packaging operations. These activities include coordination with state and Federal agencies and the international community concerned with the transportation of hazardous materials. One such activity is the Hazardous Materials Modular Training Program, which was developed to meet the regulatory requirements of the Department of Transportation (DOT; 49 CFR 172, subpart H). After this program was developed, a partnership was formed with DOT, DOE, and the National Safety Council to make it available nationwide to the entire hazardous materials community. This will give all companies involved in the transportation of hazardous materials an opportunity to obtain a high-quality, tailored training program to ensure compliance with regulations and increase the safety aspects of their activities. For DOE, this training program will save approximately \$100 million by providing training directly to the sites, which reduces travel and time away from work and eliminates the need to develop or contract out for the materials and training by providing these materials directly to the sites.

The Office of Technology Development is working to improve the management systems it uses to plan, operate,

and evaluate its work. Major efforts include documenting management plans and procedures, coordinating management efforts with other EM organizations, improving cost and schedule control systems, and improving management information systems.

FACILITY TRANSITION AND MANAGEMENT

Recent world events, presidential decisions, and Secretarial initiatives have shifted DOE priorities at numerous facilities from weapons production to environmental restoration. The Department's most challenging endeavors may be deactivating those facilities and preparing them for transition to other DOE purposes.

Before 1992, production missions at several DOE sites had been canceled. Affected production facilities were shut down and transferred to EM for final disposition. These facilities included the Fernald Environmental Management Project and the Hanford site. In addition, the Oak Ridge K-25 site was transferred to EM prior to completion of facility shutdown. The difficulties encountered in transferring these facilities uncovered the need for a dedicated organization to manage the process of transferring and dispositioning an anticipated several thousand facilities by the year 2019.

The Office of Facility Transition and Management (EM-60) was established in July 1992 to develop and institutionalize a departmental process for the timely and effective transfer of surplus facilities and to implement that process in transitioning surplus facilities to EM for final disposition. A major objective is to reduce costs to the Government by deactivating facilities that no longer have a program mission. Additional objectives of this office are to develop an accepted transfer protocol, develop plans for the transition of affected facilities and sites to EM, assess the conditions of facilities proposed for transfer (to determine priority) and the extent of anticipated transition actions, and develop site-specific mission plans for all DOE sites that support EM missions.

The office will place a special emphasis on integrating surplus facilities into the cleanup mission. As the focus shifts from production to cleanup, attention will shift to addressing work force, economic, and environmental con-

cerns, particularly on minimizing the effect on the work force and the economic impact on local communities, by focusing on economic development and conversions. A formal memorandum of agreement will be prepared to facilitate and streamline the transfer process, including management responsibilities for facility oversight.

The functions of the Office of Facility Transition and Management are divided among three offices. The Office of Facility Policy, Planning and Acceptance (EM-62) is responsible for developing the policy for facility acceptance by EM, negotiating transfers, defining the state of the facility at transfer, and developing and implementing the sitewide systems engineering planning process. The Office of Technical and Program Support (EM-63) is responsible for providing technical, management, financial, and program support to the line organizations of the Office of Facility Transfer and Management. The Office of Site and Facility Transfer (EM-64) is responsible for developing and implementing plans for the safe and orderly transition of facilities from operations to final disposition.

In January 1992, EM assumed landlord responsibilities at Rocky Flats. Five buildings and management responsibilities for residues at Rocky Flats were transferred from the Office of Defense Programs to EM. In anticipation of downsizing activities at the Rocky Flats Plant, and possibly the Mound and Pinellas Plants, three site-specific working groups were established in 1992 to develop and implement site-specific plans for transitioning these sites to EM. In July 1992, the Rocky Flats Transition Working Group completed its plan and submitted it to Congress.

In December 1992, a memorandum of agreement was signed, transferring management responsibilities for the Idaho Chemical Processing Plant from the Office of Defense Programs to EM. EM began deactivating the plant in January 1993. Also in December 1992, the Plutonium-Uranium Extraction Plant was declared surplus to the DOE mission. A directive was issued to prepare a formal plan for its deactivation. Resources were provided in 1993 to maintain the plant in a standby mode and to fund deactivation planning and the initiation of some preliminary shutdown activities.

In April 1993, the Department, EG&G Rocky Flats, and the State of Colorado signed a settlement agreement and compliance order on consent for mixed residues at the Rocky Flats Plant. The agreement settled a 1991 lawsuit filed by the state.

CHAPTER 11

GENERAL SCIENCE AND RESEARCH

INTRODUCTION

Mission

The Office of Energy Research (ER) carries out a broad range of advisory, coordination, and program management activities related to DOE's energy research and development missions and in support of the Energy Policy Act of 1992. ER responsibilities cover a broad spectrum of science, including research in the basic energy sciences, high energy and nuclear physics, fusion energy, applied mathematics and computational science, biomedical and environmental sciences, and other activities related to the Department's energy research and development (R&D) programs. The Director of ER advises the Secretary on science and technology and is the focal point for coordination with other agencies in these areas. The Director also provides management oversight of the departmentwide Small Business Innovation Research Program and carries out other responsibilities assigned by the Department of Energy Organization Act and by the Secretary pursuant to that act.

Organizational Relationships

Although some of DOE's research is funded through the various technology development programs, the majority of DOE's basic research is supported by ER. The Director of ER works closely with the various Secretarial officers on cross-disciplinary projects, plans, policies, and issues that affect their areas of interest. ER conducts technical assessments in order to advise the Secretary about gaps or duplications in the Department's R&D programs.

The Department's basic scientific research is carried out by scientists at national laboratories and universities and in industry. The Director of ER provides management oversight and coordinates with other departmental elements, as appropriate, on facilities carrying out ER's programs. The Director of ER also assists other DOE elements in assessing the scientific and technical aspects of strategic plans, multiyear plans, and budget proposals.

The Director of ER maintains close ties to representatives of industry and academia who participate in DOE-sponsored workshops, review research proposals, sit on advisory panels, and use the specialized research facilities supported by the Department. Through both

association with these groups and the widespread presentation and publication of the results of DOE-sponsored researchers at scientific conferences and in peer reviewed technical journals, the results of DOE-sponsored research are continually transferred to industry and the academic community. In addition, these activities enhance interaction between basic research and technology development and application.

HIGH ENERGY AND NUCLEAR PHYSICS

Introduction

The ER High Energy and Nuclear Physics Programs seek to expand existing knowledge about the fundamental nature of matter and energy and the basic forces that exist and interact between the fundamental constituents of matter. Such an understanding forms the basis for all the physical sciences.

The High Energy and Nuclear Physics Programs are closely related in terms of goals, the types of facilities and equipment used to reach those goals, and the impacts of one program on another. However, they have quite different research emphases. The High Energy Physics Program focuses on the elementary subnuclear particles that compose all matter, while the Nuclear Physics Program concentrates on the nucleus of the atom.

Approximately 90 percent of the total Federal support for U.S. research in high energy physics, and 85 percent in nuclear physics, comes from these two programs. Research is conducted by scientists and students from more than 150 universities and 12 laboratories nationwide, including strong international collaborations. There are approximately 1,500 scientific users of U.S. nuclear physics facilities and approximately 2,500 scientific users of U.S. high energy physics facilities. At any given time, there are approximately 500 visiting foreign scientists working at U.S. facilities. This continuing research increases knowledge about the universe, the fundamental constituents of matter, and the laws of nature that underlie all physical processes.

Such fundamental research not only helps to understand how the world works, but also leads to the development of advanced technologies needed to support continued research progress—technologies that, over the years, have had many practical applications in areas critical to the Nation's economy and national defense. These applica-

tions include therapeutic and diagnostic medical applications, computation and high-speed electronics, supercomputers, superconductivity, electricity generation, and an array of applications in industry and other scientific areas.

High Energy Physics

High energy physics research seeks to understand the fundamental nature of matter and energy. Due to this fundamental nature, research results are unpredictable and require many years before they can be turned into commercial applications. Nonetheless, such research can and does produce immediate ancillary benefits to society. For example, research results applied to other scientific fields, as well as to advanced technology and engineering, often produce practical “spinoff” devices, instruments, and technologies outside the domain of pure research. Superconducting magnet technology, high-capability computers, and medical diagnostics and treatment are such examples. Further, by working with various industries to develop state-of-the-art equipment, research physicists directly help to improve industrial processes and speed new technology to the marketplace.

Over the past two decades, much progress has been made in understanding the ultimate structure of matter. Experimental discoveries, theoretical insights, and technological innovations have made great strides toward a unified understanding of matter and energy. The results of this work, a greatly simplified picture of the physical world at its most fundamental level, are contained in the Standard Model of elementary particle physics. The Standard Model explains natural phenomena in terms of three forces—the strong nuclear force that helps describe how nucleons, and thus all matter, are held together; the weak nuclear force, which explains processes such as the radioactive decay of nuclei; and the electromagnetic force governing how atoms and molecules are formed, which is the key to understanding chemistry, electronic communications, and biological processes. The Standard Model also contains three broad classes of elementary particles—quarks, leptons, and the force-mediating particles, gauge bosons. Each class has several particles within it, essentially all of which have been observed except for the top quark and the Higgs boson.

Although experimental results to date all reinforce the predictions of the Standard Model, there are still fundamental questions to be answered. For example, have the ultimate constituents of matter been discovered? Are there

smaller particles inside the families of particles called leptons and quarks that currently are believed to be the fundamental particles? How does gravity fit into the Standard Model? Have all the forces of nature been identified?

Large particle accelerators are used to pursue the answers to these and other challenging questions. The principal experimental technique involves colliding high energy particles with fixed targets or with other particle beams. In these collisions, many entirely new forms of matter can be created by means of a series of energy-to-matter transformations. The study of these dynamic phenomena reveals the properties of the underlying building blocks and basic forces that are involved. In general, as the particles studied become more fundamental, and as their component parts are bound together more tightly, larger, more powerful and complex accelerators, detectors, computers, and ancillary equipment are needed.

Although progress in high energy physics depends on the availability of these advanced accelerator facilities, as well as on the sophisticated detectors that record the effects of particle collisions, these facilities represent only one facet of the high energy physics research program. Progress depends on a continuing interplay of advances in experiments, theory, and technology.

Generally, because of the size and complexity of a typical large research experiment, groups of physicists from universities and national laboratories team together to perform research. This team or "user group" concept is important both in terms of the research performed by the groups and for the training of tomorrow's scientists.

Typically, research teams design an experiment at their home institutions and then submit a proposal to a specific laboratory. The principal review of these proposals by each laboratory makes use of a scientific policy advisory committee. If recommended by this advisory committee and subsequently approved by the laboratory director, the user group fabricates, installs, tests, and operates the apparatus at the accelerator laboratory. The laboratory's staff of scientists, in addition to constructing, operating, and carrying out its own research with the accelerators, provides significant technical assistance to the visiting user groups. After the experimental measurements are made, the recorded data are taken back to the home institution for computer analysis and subsequent publication in scientific literature. The entire process, from conception of an experiment to publication of the results, usually takes from 3 to 8 years. At any time, there are 25 to 50 high energy physics experiments in various stages of this process. Typically, once an experiment is completed and installed, the data-taking phase extends over several years and produces a large number of scientific results.

High Energy Physics Facilities

Experimental research in high energy physics is centered at three major DOE-supported accelerator centers: the Tevatron at Fermi National Accelerator Laboratory (Fermilab; Figure 11-1), the Stanford Linear Collider (SLC) at the Stanford Linear Accelerator Center (SLAC), and the Alternating Gradient Synchrotron (AGS) at Brookhaven National Laboratory (all are described in the following sections). Each of these facilities contributes unique research capabilities to the program. Supporting technology research programs are carried out at these three accelerator centers as well as at Argonne National Laboratory, Lawrence Berkeley Laboratory, and educational and industrial institutions. These centers provide research facilities for about 1,900 physicists and more than 800 graduate students based at universities or, to a lesser extent, at the laboratories.

The Superconducting Super Collider (SSC), which had been scheduled for completion in 1999, was terminated by Congress in October 1993.

Fermi National Accelerator Laboratory

The Fermi National Accelerator Laboratory (Fermilab), located outside of Chicago in Batavia, Illinois, is home of the Tevatron, a circular accelerator 2 kilometers in diameter. The Tevatron is the world's first superconducting proton synchrotron, and it accelerates protons and antiprotons to the highest energies currently available in the world. It began superconducting operations in 1984 as a fixed-target facility and was upgraded in 1986 to also allow operation as a collider with beams of protons and antiprotons hurled against each other. Figure 11-1 shows the various facilities at Fermilab and explains the operation of the Tevatron in the collider mode.

Two major experimental detector facilities have been built at Fermilab for use in the Tevatron collider research program. One of these is the Collider Detector at Fermilab (CDF), a 4,500-ton (4,082-metric-ton) apparatus fabricated by a collaboration of physicists from the United States, Italy, and Japan. The second, the D-Zero detector, was completed and began research operations in April 1992. This detector, which effectively doubles the physics productivity of the Tevatron by operating simultaneously with the CDF, is also complementary to the CDF in its detection techniques and physics capabilities.

The top priority for the current collider run, scheduled to extend through the end of 1994, is the search for the top quark. Other important goals include precisely mea-

11-1. Tevatron at Fermilab. A series of four accelerators boosts protons to almost the speed of light. Antiprotons are created and stored in the antiproton source before being injected into the Tevatron in the opposite direction from the protons. Superconducting magnets guide the particles around the Tevatron. Each time a bunch of particles passes through an accelerating station, radiofrequency waves increase the energy of the particles until the bunches make nearly 50,000 round trips each second. When the protons and antiprotons collide, sophisticated detectors track, identify, and record the new particles that are made from the energy of the collision. Protons and antiprotons continue to circulate and collide until there are not enough particles left for efficient operation, and the process begins again.

asuring the W boson mass, probing for evidence of quark substructure, and measuring the properties of B mesons.

Construction continues on the Main Injector project at Fermilab. The Main Injector is a new, rapid-cycling, conventional magnet, 150-GeV (24-nanojoule) accelerator in its own ring tunnel. It will inject beams into the Tevatron, replacing the 20-year-old Main Ring accelerator. When completed in 1999, the Main Injector will increase the luminosity of the Tevatron collider by three to five times. In addition, it will enhance Fermilab's overall research capabilities by allowing simultaneous operation of the fixed-target and Tevatron collider research programs.

The Fermilab Linac Upgrade construction project, which started in October 1989, began commissioning with beam in August 1993. This project replaces half of the 440-foot- (134-meter-) long original Fermilab linear accelerator (linac) with new accelerating structures capable of a very high electric field gradient, so that the final energy of the accelerated beam can be doubled, from 200 to 400 mil-

lion electronvolts (MeV) (32 to 64 picojoules). Within 1 week of initial operation, the beam reached its new design energy goal—a remarkable feat, given that other linear accelerators have taken weeks to accomplish this. The upgraded linac, which is now fully operational, has met both its energy and intensity design goals. This upgrade greatly increases Fermilab's high energy physics research capabilities and discovery potential.

Stanford Linear Accelerator Center

The second largest U.S. accelerator center is the Stanford Linear Accelerator Center (SLAC), located at Stanford University in California. In 1988, this facility was upgraded by the addition of the Stanford Linear Collider (SLC) to provide for collisions of electrons and positrons (the anti-particles of electrons). This new configuration, the SLC, is depicted in Figure 11-2. The SLC combines a linear accelerator with rings of magnets that bring the electron

11-2. Stanford Linear Collider.

and positron beams into head-on collision. The SLC was designed to produce Z particles (the neutral particles that carry the weak force), which may help physicists in their efforts to validate and probe the Standard Model.

In 1989, the SLC's luminosity was increased by a factor of 3. This higher luminosity is used by the more powerful Stanford Large Detector, which began operation in 1991, to study high energy electron-positron interactions and certain aspects of the Z particle. In 1992, further increases were achieved in the SLC luminosity, and the SLC was upgraded to accommodate polarized beams. The SLC thus has a capability for studying polarized electron-positron interactions that is unique in the world.

In October 1993, SLAC was selected as the site for construction of an Asymmetric B-factory. The B-factory will collide ultrahigh-intensity beams of electrons and positrons (the electron's antimatter counterpart) to create tens of millions of subatomic particles called B mesons. Detailed studies of the properties of these particles will help scientists explain the existence of matter and help answer one

of the most fundamental questions of elementary particle physics: Why the universe now consists of matter, when shortly after the beginning of the universe matter and antimatter existed in equal proportion.

The B-factory, which is scheduled for completion in 1998, will be designed and built by SLAC in collaboration with Lawrence Berkeley Laboratory, Lawrence Livermore National Laboratory, and other research institutions. An existing accelerator, known as the Positron-Electron Project (PEP), will be modified for the new facility. Beams of electrons and positrons will be injected into two rings where they will circulate in opposite directions at unequal energies. The beams will be brought together inside a detector with a total collision energy of about 10.6 billion electronvolts (1.6 billion attojoules).

Research also continues at SLAC on the next generation of high energy electron-positron linear colliders that could operate in the energy regime of about 250 GeV on 250 GeV (40 nanojoules on 40 nanojoules). SLAC and other laboratories throughout the world are performing

research on the linear collider concept, which will continue over the next several years. Construction of the next-generation high energy linear collider could start either in the United States or abroad within the next 10 years.

Alternating Gradient Synchrotron at Brookhaven

The Alternating Gradient Synchrotron (AGS) at Brookhaven National Laboratory lets scientists study the intermediate energy range of protons at energies up to 33 billion electronvolts (5.3 nanojoules), and of heavy ions at energies up to 14 billion electronvolts (2.2 nanojoules), per unit of mass. The AGS is the only facility in the world that can produce high energy polarized-proton beams of such intensity; it is used both for high energy physics studies of fundamental particles and for nuclear physics studies of the structure of nuclei. Brookhaven National Laboratory completed construction of an AGS booster accelerator in 1991, and it was brought into operation in 1992. The booster provides a fourfold increase in AGS beam intensity and a twentyfold increase in the intensity of the polarized beam, and also allows the acceleration of ions with masses as heavy as gold, thus providing the world's most intense beams of such heavy ions.

Superconducting Super Collider

In October 1993, Congress voted to discontinue construction of the Superconducting Super Collider, and the Energy and Water Development Appropriations Act of 1994 provided \$640 million for the orderly termination of the project. This report provides information on the activities and accomplishments for 1992 and 1993. Subsequent reports will provide information on SSC termination activities and the Department's efforts to maximize the value of the investment that has been made in the project.

The SSC was to provide scientists worldwide with capabilities 20 times more powerful than those of existing proton accelerators—thereby continuing to expand the frontiers of knowledge and understanding of the basic elements of matter and energy. With its energy of 20 trillion electronvolts (3.2 trillion attojoules) per beam, the SSC was expected to be the world's preeminent facility for high energy physics research and to serve as a major resource for science education. The principal feature of this proton-proton collider was a proton injector system that would inject 2-trillion-electronvolt (320-billion-attojoule) proton beams into a large collider ring containing two rings of superconducting magnets located in an underground tunnel 54 miles (87 kilometers) in circum-

ference. The two rings of magnets were to steer and focus the proton beams in opposite directions until they were made to collide at the various interaction regions, where large detectors would have recorded the resulting events for later analysis by physicists.

International participation in the SSC continued to grow in 1992 and 1993. Government-to-government agreements were signed with the Chinese Academy of Sciences in the People's Republic of China (PRC) and the Russian Federation Ministry of Atomic Energy during 1992. These agreements provided a framework for Interlaboratory Collaborative Agreements and for exchanges of personnel between the Superconducting Super Collider Laboratory (SSCL) and institutes in the PRC and in the Russian Federation. The SSCL concluded 12 interlaboratory agreements with Russian Institutes, and two interlaboratory agreements with the Institute of High Energy Physics in Beijing. Each of these agreements produced contributions to the SSC, with partial compensation to collaborating institutes. The SSCL had also concluded one interlaboratory agreement with the Center for Advanced Technology in India. In 1993, additional interlaboratory agreements were under consideration with institutes in the Republic of Belarus and in Israel. Joint Working Groups continued to meet with representatives from Japan and the Republic of Korea, and exploratory discussions were held with representatives of Canada, Finland, Italy, Mexico, and Saudi Arabia concerning possible participation in the SSC.

The SSC was expected to maintain the United States' position as a world leader in science and technology and reflect the nation's commitment to scientific leadership. In the Department's view, SSC construction and operation were congruent with current priorities assigned to technological advancement and its economic benefits. The anticipated economic benefits were both near-term (the benefits from constructing the SSC) and long-term (the forthcoming benefits from the basic research to be conducted during operation). The SSC and its related technological innovations could have profoundly affected industrial and technological development in the 21st century.

During 1992 and 1993, the State of Texas, through the Texas National Research Laboratory Commission, continued to acquire land and other facilities required for the SSC at no cost to the Federal Government. By the end of 1992, the State of Texas had acquired nearly 90 percent of the surface land requirements and nearly 80 percent of the subsurface land requirements, as well as the 500,000-square-foot (46,500-square-meter) Central Facility in Waxahachie, Texas. In addition, the State of Texas had agreed to provide approximately \$1 billion to support the SSC.

Throughout the life of the project, there was significant progress in the design and construction of the SSC. During 1992, the SSC reached a landmark when a 100-meter-long string of superconducting magnets was successfully tested under full operating conditions at the Accelerator Systems String Test facility. The test, which was completed 6 weeks ahead of schedule, verified superconducting magnet designs and demonstrated other critical technical systems for the collider ring.

On April 8, 1993, the first acceleration of beam at the SSC was accomplished. A beam of H^- ions was accelerated through the Radio Frequency Quadrupole (Figure 11-3) to a final kinetic energy of 2.5 million electronvolts (400,550 attojoules). The Linear Accelerator Facility, the first of four facilities that were to accelerate protons before their injection into the main ring, was turned over to the SSCL for equipment installation during mid-1993. By September 1993, more than 14 miles (22 kilometers) of collider main ring tunnel had been excavated; and new world records were established at the SSC for number of feet of tunnel excavated in a single period (1 day, 1 shift, and 1 week).

An aerial view of the Linear Accelerator Facility is shown in Figure 11-4. Figure 11-5 is an aerial photograph of the N15 site showing the Accelerator String Test Facility, the Magnet Development Laboratory, the Magnet Test Laboratory, and the Magnet Delivery Shaft. One of the Tunnel Boring Machines used for tunneling the main collider ring is shown in Figure 11-6.

There had also been significant progress in magnet design and production. Collider dipole magnets and quadrupole magnets passed preliminary design reviews. By the end of 1992, 20 prototype, collider dipole magnets and 6 collider quadrupole magnets had been built and tested.

11-3. Radio Frequency Quadrupole at the SSC.

Testing confirmed the collider magnet designs, and manufacture of preproduction model magnets was to begin with General Dynamics and Westinghouse Electric Corporation for collider dipole magnets. Westinghouse Electric Corporation was working on High Energy Booster dipole magnets, and Babcock and Wilcox was working on the collider quadrupole magnets. These preproduction models were expected to demonstrate the manufacturing process and tooling before full production of magnets.

SSC experimental physics research was scheduled to begin in the year 2002 with two large detectors with complementary capabilities. Planning and design for these two detectors, the Solenoidal Detector Collaboration (SDC) and the Gammas, Electrons, and Muons (GEM) collaboration, continued in 1992 and 1993. The SDC was an international collaboration of more than 900 physicists and engineers from 116 institutions in 17 nations. The technical design report for the SDC detector was approved by the Department of Energy in 1992. The GEM collaboration consists of more than 1,000 scientists from 114 institutions in 17 nations. The technical design report for the GEM detector was submitted for review in April 1993. Many of the world's most distinguished high energy physicists participated in these two large collaborations. The SSC Users Organization, which consisted of more than 4,000 scientists and engineers engaged in high energy physics research, included approximately 1,700 members from nations outside the United States.

11-4. Linear Accelerator Facility at the SSC.

11-5. NI5 SSC site.

Creating an international resource for all levels of education was one of the primary goals of the SSC. During 1992, more than 30,000 students and adults participated in SSC educational programs and activities. The programs were intended to stimulate interest in science and mathematics while working with educators to improve education overall. Planning and development of the International Science Education Center continued during 1993. The center was to offer a unique forum where educators and scientists could work together to address significant issues facing education in science, mathematics, engineering, and technology, from preschool through adulthood. Also in 1993, the Department, the SSCL, and the Prince William County School System in Virginia cosponsored the broadcast of two 1-hour science programs. The free satellite downlink was viewed by more than 1 million students at 1,000 schools.

During 1993, the Secretary announced several initiatives to enhance DOE oversight of the SSC and reduce the risks of cost growth and schedule delays. The Secretary directed implementation of the following six-point action plan: (1) review contract options for the SSC, (2) review the departmental and laboratory management structure for the project, (3) strengthen the Department's onsite management capabilities, (4) prepare an all-inclusive revised cost and schedule baseline, (5) assess laboratory leadership, and (6) strengthen departmental oversight through standard reviews and annual appraisals.

11-6. Tunnel Boring Machines at the SSC.

During July 1993, the Department conducted a baseline validation review, which confirmed that SSC construction was within budget and on schedule. The Department committed to aggressively manage the cost risks identified by this review to minimize their impact on SSC cost and schedule. Initiatives in 1993 included the development of an implementation plan for baseline validation review recommendations, establishment of value engineering teams to review cost risk areas, and review of the current project design to identify cost savings without affecting scientific objectives. The Department conducted a review to validate the SSCL Project Management Control System and initiated corrective action to improve the system.

Research Highlights

The Search for the Top Quark

The Tevatron at Fermilab began an extended period of data collection in August 1992. By December 1992, it achieved a new world record for intensity of proton-antiproton collisions that broke the previous record held by the European Center for Nuclear Research (CERN) in Geneva, Switzerland, and considerably exceeded Fermilab's stated goal for the run. More recently, the collider has achieved even greater luminosity. Both the Collider Detector at Fermilab (CDF) and D-Zero detector collaborations will continue to search intensively for the elusive top quark, the last remaining unobserved particle predicted by the Standard Model. Recently, scientists using the CDF recorded one event that may have provided a glimpse of the top quark; however, a single observation

cannot establish its existence—many additional supporting observations are necessary. No matter what the outcome, this research provides a crucial test for the validity of the Standard Model. This accomplishment has received the most attention because of its significance, but there are also other physics experiments being conducted that are yielding scientific data, for example, on other aspects of the Standard Model.

Z Interactions of Polarized Electrons

In late spring 1992, the Stanford Linear Collider began generating scientific results using a new beam of polarized electrons, a capability unique to the SLC. In these experiments, a high energy beam of polarized electrons collides with an unpolarized beam of positrons to produce what are referred to as Z particles, the heaviest known elementary particle. The Z particles produced at SLAC are the first to be produced by polarized electrons. This unique polarized-beam capability gives physicists an added degree of control over the experimental conditions and provides scientific results that cannot be duplicated by any other laboratories in the world. More than 11,000 Z particles had been observed and recorded by September 1992, surpassing the goal set for the experimental run. In the current run, the polarization has routinely been about 60 percent, well above the 1993 goal of 40 percent, and the data rate is about 4,000 Zs per week and increasing.

Electron-Positron Linear Colliders

The long-term future of research using electron-positron linear colliders is also being studied at sites worldwide. These devices require extraordinarily small beams; SLAC is conducting R&D to produce the smallest-diameter high energy particle beam ever seen. Apparatus for this R&D is currently being assembled at SLAC through an international collaborative effort involving scientists from the United States, the Russian Federation, Japan, France, and Germany. The first experimental results are expected in the next year or so.

Proton Acceleration, Kaon Decay Studies, and the Accelerator Test Facility at Brookhaven

At the Alternating Gradient Synchrotron at Brookhaven, physicists successfully brought into operation the new booster injector synchrotron, which is an addition to the main accelerator complex. The AGS delivered protons to 10 running experiments and 30 different test beam groups. In addition, the injector linac, a component of the AGS

that can operate separately, provided beams for testing materials for the Superconducting Super Collider and for the production of radiopharmaceutical isotopes.

Scientists also continued to study the rarest modes of kaon particle decays. (Kaons are very short-lived particles that can be copiously produced by the AGS.) The Standard Model predicts that certain specific decays of the kaon will occur only about once in every 10-billion kaon decays. One experiment has already shown that the predicted decay occurs fewer than three times in a billion ordinary decays, which is still somewhat above the predicted rate. As the experiments continue, ultimately scientists plan to measure decay rates down to, and perhaps below, the predicted level, thus providing another crucial test for validation of the Standard Model.

At the Center for Accelerator Physics at Brookhaven, the Accelerator Test Facility (ATF), designed to test the principles of acceleration of charged particle beams with lasers, was completed and brought into operation. The ATF comprises a 50-MeV (8-picojoule) linear electron accelerator in conjunction with several lasers. The ATF experimental program consists of a set of experiments that study the interaction of the lasers with the electron beam from the linac. The objective of these experiments is to identify interactions that accelerate the electron beam to higher energies. Initial operation produced a 45-MeV (7.2-picojoule) energy electron beam with the highest "brightness" known. High brightness is essential for matching the electron beams to be accelerated to the laser beams that will perform the acceleration. The ATF experimental program has now started; the CO₂ laser system has been completed and has operated at the 10-to-20-gigawatt power level. With this laser, the Inverse Cerenkov experiment, the first approved experiment in the ATF experimental program, started taking preliminary data using the high energy beamline at the ATF.

Discovery of the B_s Meson

As part of the broad international collaboration and cooperation in high energy physics, U.S. physicists are substantially involved in all four experiments (ALEPH, DELPHI, L3, and OPAL) at the Large Electron-Positron collider at the CERN Laboratory in Geneva, Switzerland. The ALEPH collaboration recently announced the discovery of the B_s meson, which in the Standard Model consists of a "bottom" quark and a "strange" quark. The ALEPH team also determined its mass. This long-awaited discovery paves the way for studying quantum properties of the B_s meson. The University of Wisconsin team led the data analysis effort for this discovery.

Nuclear Physics

The Nuclear Physics Program studies the properties and structure of atomic nuclei. To do this, nuclear physicists must also understand the effects of the strong nuclear force and the electroweak force on the elementary particles that make up nuclear matter. Nuclei are constructed of anywhere from one to several hundred nucleons (protons and neutrons), depending on the element. Furthermore, nucleons themselves are composed of quarks and gluons.

Calculating nuclear structure based on these particles is referred to as a “many-body problem” because of the tremendous mathematical difficulties associated with solving equations that describe the interactions of as few as three mutually interacting objects. For example, the many-body problem for three interacting objects, such as stars where the forces between them are well known, is barely solvable; for four or more it is solvable only by relying on approximations that simplify the calculations. Within the mathematical constraints imposed by the many-body problem, nuclear physicists are attempting to understand the structure of nuclei in terms of their constituent particles, the dynamics of nuclei in terms of the motions of those particles, and the fundamental forces between the particles that govern those motions.

Until the last few years, scientists characterized their understanding of the behavior of atomic nuclei in terms of relatively simple models. As one example, collective models view nucleons as moving in concert (collectively) in ways that may be simple or complex—just as the molecules in a flowing liquid may move smoothly or turbulently. In the simplest collective model, the nucleus is viewed as a drop of nuclear fluid, which can assume a variety of spheroidal shapes; it is almost incompressible, and can rotate and vibrate over a wide range of frequencies. It was in terms of such a model, which has been highly successful in interpreting the energy-level structure of nuclei as they rotate and vibrate at relatively low frequencies, that scientists came to understand nuclear fission. Despite their success, however, the collective models do not directly incorporate the known fundamental many-body substructure of nuclei.

Equally simple independent-particle models, however, allow the motion of a single nucleon, in a trajectory similar to that of an electron in an atom or that of a planet around its sun, to be examined in terms of a steady, average force field produced by all the other nucleons. In a further development of the independent-particle model, the average force field of the nucleus influences the motion of pairs of nucleons, where there are strong interac-

tions between these pairs, as, for example, the Earth and the Moon rotate around each other as they both orbit the Sun. This pair interaction within nuclei is based on measurements of the interaction between independent neutrons and protons. However, this pair interaction both influences, and is influenced by, the average force field of all the other nucleons. An understanding of the relation between these two extreme simple models of the nucleus is still only qualitative, and active theoretical research by DOE scientists continues in this area. The ability to do a full many-body calculation based on realistic strong interactions still far exceeds present theoretical capability.

In the traditional model of the interactions between the nucleons within the nucleus, the nuclear force arises from the exchange of particles, called mesons, between the two interacting nucleons. It is now understood that the nucleon can be pictured as an assemblage of three quarks, and that the mesons that mediate the nucleon-nucleon interaction can be pictured as quark-antiquark pairs, and that both are held together through the exchange of gluons as described by the quantum chromodynamics theory. There is evidence that some properties of the nucleus can be understood only when this quark-gluon substructure is explicitly accounted for. However, a satisfactory description of even the nucleon-nucleon interaction in terms of various quark and gluon interactions does not exist, because of the complexity of the quantum chromodynamic force. The role of the quark-gluon substructure in nuclear physics will be a major area of research in nuclear physics.

Applications

The ability to use the special features of the atomic nucleus has produced technologies of inestimable value, including civilian and military uses of energy from nuclear fission and fusion, the myriad uses of radioactive isotopes in medicine and industry, the management of the nuclear fuel cycle, methods to assess new materials crucial to technological development, and methods for geophysical assays used by the oil industry. DOE's National Nuclear Data Center at Brookhaven helps evaluate and disseminate such data on nuclear properties to private industry and the research community. The Nuclear Physics Program manages this activity (because of its technical expertise and interest) on behalf of its diverse clientele.

Nuclear Physics Resources

The Nuclear Physics Program supports the research of approximately 1,600 scientists and 400 graduate students. To develop the broad understanding of nuclear physics

outlined above, these researchers must study a wide variety of nuclear species under many extreme conditions of temperature, pressure, density, and rotational and vibrational frequencies. Such work requires a variety of particle accelerators to accelerate beams of many masses over energies from the 1-million- to 10-million-electronvolt (0.2- to 1.6-picojoule) range up to energies a hundred or a thousand times that amount.

The low energy heavy-ion accelerators at the Argonne, Lawrence Berkeley, and Oak Ridge National Laboratories are used to study rapidly rotating, hot nuclei. DOE also operates comparable low energy heavy-ion accelerators at four universities: Texas A&M, Yale, the University of Washington, and Duke, operated by the Research Triangle universities in North Carolina (Duke University, the University of North Carolina at Chapel Hill, and North Carolina State University). These facilities focus on the properties of nuclear surfaces when they rotate or vibrate after they collide and how nucleons move at the nuclear surfaces. In an interesting special case, the mechanisms by which nuclei "breathe" (that is, how they expand and contract while maintaining a spherical shape) are being examined. Such research provides data that can be interpreted to measure the stiffness of nuclear matter and thus describe the strength of the nuclear force as a function of the distance between nucleons. This, in turn, provides data that are proving essential to understanding how supernovas explode. DOE supports these facilities for both in-house research and student training.

Augmenting these facilities are accelerators that operate at higher energies to explore the physics in the center of nuclei, not just at their surfaces. By slamming nuclei together at even higher energies, the Bevalac Accelerator at Lawrence Berkeley (closed in February 1993) and the Alternating Gradient Synchrotron accelerator at Brookhaven form nuclear matter at the densities of stars, but at even higher temperatures. At the Clinton P. Anderson Meson Physics Facility at Los Alamos National Laboratory, the world's most intense beams of high energy protons are used to study the interactions of these protons with nuclei, and to produce many secondary beams of neutrons, mesons, and neutrinos. The secondary beams are used to study the role of mesons in nuclei. At present, the best techniques for studying the role of mesons and quarks deep in the nuclear interior use the electron probes of the electron accelerators at the Bates Laboratory at the Massachusetts Institute of Technology, Cambridge, and at the Stanford Linear Accelerator Center. This type of research will be dramatically improved with commencement of the operation of the Continuous Electron Beam Accelerator Facility in 1995.

Research Highlights

The Always Elusive Neutrino

An early triumph of nuclear physics was the speculation by Enrico Fermi in the 1930s that when the neutron transforms to the proton by the emission of an electron (a process known as beta decay), a third massless, chargeless, almost-impossible-to-detect particle, the neutrino, is emitted. The neutrino was required if energy and angular momentum were to be conserved in the beta decay of radioactive nuclei. However, the existence of this elusive particle was not directly confirmed until much later by detection of neutrino-induced reactions at high energy physics accelerators.

Understanding the neutrino is crucial to answering questions in many areas of nuclear physics, particle physics, and astrophysics. A major general question is: Do neutrinos perhaps have a mass? Large fluxes of neutrinos are produced in the series of nuclear reactions of the Sun, but fewer than one-third of the expected number of these neutrinos arising from secondary processes have been detected at the Earth's surface in previous DOE-funded experiments. Large detectors were developed in Russia and Europe in collaboration with DOE-funded nuclear physicists to study this problem, based on the primary solar burning process. Preliminary results from the two sites, using the Soviet-American Gallium Detector (SAGE) and the U.S.-European GALLEX detector, again indicate an unexpectedly small neutrino flux reaching the Earth. A widely accepted explanation of this anomaly is that neutrinos do indeed have a very small mass, permitting transmutation into types of neutrinos for which present detectors are insensitive. Alternatively, but less likely, an incorrect understanding of the temperature and structure of the solar core might account for the discrepancy.

Cosmological models suggest that only 10 percent of the total mass of the universe is accounted for. Where is the rest? If the neutrino has a small mass, is the rest of the mass accounted for in these almost-invisible particles? The tantalizing evidence for neutrino masses is the first evidence of physics beyond the Standard Model of fundamental interactions, which has formed the basis of high energy and nuclear physics for more than a decade.

Superdeformation

A major advantage of using accelerated heavy ions to study nuclear structure is that the projectiles can induce target nuclei to rotate at very high angular frequencies. When nuclei are essentially at rest or rotating very slowly, they

have a nearly spherical or football-like shape. After collisions with projectiles, some nuclei can further deform into cigarlike shapes; these nuclei are referred to as "superdeformed nuclei." The numbers of these superdeformed nuclei that are very rigid over wide ranges of rotational frequencies and whose shape remains essentially unchanged as protons and neutrons are added to form more massive systems have increased over the last several years. The unexpected stability of shape between nearby nuclei suggests an underlying symmetry principle that is not yet understood. There is growing evidence that this systematic correlation is widespread and occurs for shapes other than the superdeformed mode. Initial experiments with the partially completed Gammasphere detector system at Lawrence Berkeley, which began construction in 1991 and should be completed in 1995, are beginning. Upon completion, this device will allow much more precise experimental investigations of these intriguing shape effects.

Quarks in Nuclei

More than a decade ago, experimental results from the European Muon Collaboration (EMC) at the CERN Laboratory in Geneva, Switzerland, and from the Stanford Linear Accelerator Center, after comparison with theoretical predictions, could be interpreted as evidence that the spin (angular momentum) of the nucleon is not carried by the quarks that make up the substructure of the nucleon. This result has been referred to as the "spin crisis" within the physics community. The experimental procedure used for these experiments, deep inelastic muon or electron scattering with polarized beams and polarized targets, directly probes the distribution of the spin of the nucleon quark constituents. The resulting data can be used to extract information that provides a direct test of quark models of nucleon structure.

To shed further light on the "spin crisis," the DOE Nuclear Physics and High Energy Physics Programs and the National Science Foundation are jointly supporting a new generation of experiments by the Spin Muon Collaboration (SMC) at CERN and the experiment E142 collaboration at SLAC to provide new data that considerably extend the previous limited results. Recent results from SMC using a deuteron target and from E142 using a helium-3 target are giving the first look at the neutron spin structure. These early data indicate that, within the errors, the experiments are consistent but not yet definitive. More extensive and accurate data are required to increase confidence in the validity of theoretical predictions on the origin of the nucleon's spin. The continuation of SMC, a new SLAC experiment E143, and a new experiment at

the DESY laboratory in Germany will gather data on both the proton and neutron, which should provide the requisite new information.

New Research Facilities

The role of quantum chromodynamics theory and quarks and gluons in nuclear physics will be a future major component of the Nuclear Physics Program. Probing nuclear matter at a resolution sufficient to be sensitive to quarks will require precision beams of high-energy particles. Two large DOE facilities now under construction—the Continuous Electron Beam Accelerator Facility and the Relativistic Heavy Ion Collider—will provide these needed beams. DOE will devote a large portion of its nuclear physics effort to completing and bringing into operation these facilities over the next few years.

Continuous Electron Beam Accelerator Facility

The Continuous Electron Beam Accelerator Facility, now under construction in Newport News, Virginia, will be an electron accelerator that will use superconducting technologies to produce a continuous beam of electrons of unparalleled precision and quality, in the energy range from 0.5 billion to 4 billion electronvolts (0.08 to 0.64 nanojoule). This facility is scheduled to become operational in 1995. This range of beam energies will be needed to study the transition from conventional meson-oriented nuclear physics at the lower energies to a quark-based description of nuclear physics at top energy and to provide DOE researchers a means to measure the role of the quark substructure in nuclear matter.

Civilian construction of the underground tunnel that will house the approximately three-quarter-mile (1.21-kilometer-) -circumference accelerator ring has been completed, and the helium refrigerators that will cool the superconducting magnets to only 2 degrees above absolute zero are installed and being tested. The injector and most of the superconducting accelerator have been installed and successfully tested.

The Continuous Electron Beam Accelerator Facility is being constructed by, and will be operated by, Southeastern Universities Research Associates, with 41 member universities from 13 states and the District of Columbia. More than 30 proposals for experiments, involving more than 250 physicists from 34 institutions, have been approved for research time by program advisory committee action. Figure 11-7 shows experimental Hall B construction; Figure 11-8 shows the accelerator cryomodule assembly and alignment process.

11-7. Hall B of CEBAF.

Relativistic Heavy Ion Collider

Quantum chromodynamics postulates that nucleons and mesons are made up of quarks, but no one has ever seen a quark deconfined from a nucleon or meson. In fact, theory predicts that deconfinement can occur only in nuclear matter. Cosmology models infer that about one-millionth of a second after the universe formed, matter consisted of a hot soup of deconfined quarks called the quark-gluon plasma.

When two gold ions collide at high enough energies, the reaction is expected to reproduce such a quark-gluon plasma. The hot, dense nuclear matter that is a precursor of such a plasma is being studied at the Alternating Gradient Synchrotron accelerator at Brookhaven and elsewhere, and previously at the Bevalac facility at Berkeley. Although these experiments have increased the confidence that nuclear matter in the hot, dense form required for the plasma can be produced at higher energies, they have not been able to produce the plasma.

A second new facility, the Relativistic Heavy Ion Collider, now in its third year of construction at Brookhaven, has been designed specifically to study the quark-gluon plasma. Studies there will use colliding beams that provide collision energies of 100 billion electronvolts (16 nanojoules) per nucleon for ions as massive as gold nuclei. The Relativistic Heavy Ion Collider construction project takes advantage of extensive facilities already in place at Brookhaven, including the accelerator tunnel and experimental halls and a refrigeration plant that can support the nearly 1,700 superconducting magnets that will be built and installed during the course of the project. The existing Tandem Van de Graaff, Booster, and AGS accel-

11-8. CEBAF cryomodule assembly and alignment process.

erators will be used to inject the heavy ions at the energy needed for final acceleration, storage, and collision in the Relativistic Heavy Ion Collider's rings. The stored heavy ions will be able to circulate for 10 hours before beam losses require the rings to be filled again.

DOE made excellent progress during the first year of construction, including contracting for the required superconducting cable and superconducting magnets. Key personnel are in place for all collider subsystems, and installation of magnet stands and utilities is under way. In preparation for the experimental program, scheduled to begin in 1999, DOE is formulating plans for the initial complement of detectors to measure the reaction products emitted by the plasma after the collisions. Nine preliminary experimental detector proposals involving some 450 scientists from 50 institutions have been condensed into 2 major detectors. The STAR detector will use a time-projection-chamber concept in a solenoid magnet to measure trajectories of charged particles. The second detector, the PHENIX, will focus on electron and photon measurements in a flat-field magnet. University and national laboratory groups are also developing plans for experiments involving two smaller detectors.

BASIC ENERGY SCIENCES

The Department's Basic Energy Sciences (BES) Program provides the fundamental scientific and engineering knowledge to enable the Nation to meet its future energy needs through basic research on advanced technologies for energy production, conversion, and use. Research aimed at

improving existing energy technologies is extremely important; but even more important is basic research that lays the foundation for future, as yet unknown or undeveloped, energy sources. A comprehensive program of basic energy-related research is therefore essential to the Department's missions.

BES research is carried out primarily at DOE national laboratories, universities, and, to a lesser extent, private industrial facilities. The BES Program supports more than 1,300 individual research projects, each selected because of its scientific merit, its relevance to the Department's long-range energy research goals, and its contribution to meeting the Nation's technology needs. These projects are continually evaluated to maintain a balanced and diverse basic research portfolio; as a result, some efforts are discontinued to support new, more promising areas.

A large portion of the BES national laboratories budget is for operating large, complex scientific user facilities; supporting research dependent on these facilities; and providing services uniquely available at the national laboratories. Many areas of modern science require these major facilities to develop information not otherwise attainable; and in general, only the Federal Government can provide the necessary commitment of funds, and only the national laboratories have the needed expertise to support such facilities. These facilities include the High Flux Beam Reactor at Brookhaven National Laboratory; the High Flux Isotope Reactor at Oak Ridge National Laboratory; the Intense Pulsed Neutron Source at Argonne National Laboratory; the Los Alamos National Laboratory Neutron Scattering Center; the Advanced Light Source at Lawrence Berkeley Laboratory (Figure 11-9), which recently was successfully completed on time and within budget; the Stanford Synchrotron Radiation Laboratory; and the Combustion Research Facility at Sandia National Laboratories-Livermore. A new synchrotron light source, the Advanced Photon Source at Argonne, is under construction for research in the x-ray radiation regime to complement the ultraviolet radiation regime of the Advanced Light Source; work is planned to be completed by September 1996. The conceptual design of a new research reactor, the Advanced Neutron Source, was completed in June 1992 by a project team at Oak Ridge National Laboratory; and this design is continuing with an environmental impact statement, safety-related design elements, and research and development on specific components.

The BES Program is guided by ideas from scientists, peer reviews, and advice from the academic, industrial, and government research community, including the Basic Energy Sciences Advisory Committee, which is composed of eminent scientists and engineers from a variety

11-9. Advanced Light Source at Lawrence Berkeley.

of disciplines. The BES Program supports research in materials sciences, chemical sciences, engineering and geosciences, energy biosciences, and advanced energy projects.

Materials Sciences

The Division of Materials Sciences' research program aims to increase understanding of materials properties, behavior, phenomena, and synthesis, and of the processing of those new classes of materials important to the Department's missions. Such understanding contributes to the development of new or substitute materials, the tailoring of materials to meet defined needs, and the prediction of materials problems and their service life. Research concentrates on selected areas of fundamental importance and on areas where problems are known to exist or are anticipated. Materials sciences encompasses metallurgy, ceramics, solid-state physics, and materials chemistry.

Some materials sciences research has a specific relationship to an identified energy technology (such as research on photovoltaic materials for converting solar energy into electricity or research on radiation damage); some is related to many energy technologies simultaneously (such as research on hydrogen embrittlement, corrosion, superconductivity, magnetic materials, or welding science); and some is important to fundamental understanding of new experimental and theoretical research tools to improve the

capability to analyze and measure the basic structure and properties of materials and to predict the behavior of potentially promising new materials.

In addition to maintaining an appropriate mix of long-term energy technology-related research, the Division of Materials Sciences' research program also supports the development of new forefront analytical instruments and facilities used to probe the structure and behavior of matter. Thus, this program has a major responsibility for the design, construction, and operation of many of the Nation's premier research facilities (for example, the High Flux Beam Reactor at Brookhaven; the Advanced Light Source at Lawrence Berkeley Laboratory; electron microscopy centers at Oak Ridge, Argonne, Berkeley, and the University of Illinois; and the Advanced Photon Source under construction at Argonne) that are used by investigators throughout the research community and for special Department of Energy needs.

Research Highlights

Advanced Light Source at Lawrence Berkeley Laboratory

The Advanced Light Source at Lawrence Berkeley Laboratory, a national user facility providing high-brightness beams of ultraviolet and soft x-ray light, is expected to create invaluable new opportunities essential for maintaining the progress and competitiveness of U.S. science and technology (Figure 11-9). This exciting new facility will offer incomparable scientific and technical opportunities and serve a broad spectrum of scientific fields, including materials research, biology, chemistry, atomic and molecular physics, plasma physics, earth sciences, and medical science. The Advanced Light Source will affect information and defense technologies, as well as those of energy, transportation, and health.

Completed 1 full week ahead of schedule and within budget, the Advanced Light Source, the first U.S. third-generation synchrotron radiation source, exceeded the baseline performance requirement for project completion by achieving 65 milliamperes of electron-beam current in its storage ring—well above the 50-milliamperes milestone set by DOE. On March 31, 1993, the actual project completion deadline, the beam current far surpassed all expectations, reaching 290 milliamperes. By April 9, 1993, the current exceeded the 400-milliamperes design goal, reaching 407 milliamperes. This achievement is one of a series associated with the design, construction, and commissioning of the Advanced Light Source; electron beam current was stored on the same day the radio frequency system

was activated, and each step since has been an unqualified success, culminating when light first passed down a beamline on October 4, 1993. The facility also began operations for its scientific program in October 1993. The Advanced Light Source was formally dedicated on October 22, 1993, and it is expected that five experimental beam lines will be operational in 1994.

Adhesion

Sandia National Laboratories-Albuquerque developed a new surface force apparatus, the Interfacial Forces Microscope, in 1992 and used it to measure the mechanical relaxation of an organic film, a single molecule thick, on a metal surface while the film is interacting with a microscopic tungsten tip. The microscope showed that the monolayer film drastically altered the adhesive properties of the metal surface. There was a delayed elastic response, which has important implications for the development of improved lubricants and adhesives.

These microscopic measurements, the first ever, are important to understanding macroscopic phenomena such as friction, lubrication, and adhesion. A new cooperative research and development agreement (CRADA) involving Sandia, Digital Instruments, American Telephone & Telegraph Bell Laboratories, and the University of New Mexico has been signed to develop a commercial Interfacial Forces Microscope.

Electroincineration

Research at Ames Laboratory demonstrated for the first time a fast and complete electroincineration of a toxic family of organic compounds. (Electroincineration is the electrochemical oxidation of organic waste materials into harmless byproducts, that is, carbon dioxide ions and hydrogen ions.) This research led to the discovery of new, inexpensive, and rugged electrode materials and techniques for the fast and complete electroincineration of benzene and its derivatives. Benzene, a carcinogen, is a ubiquitous and troublesome chemical waste. The Ames electroincineration technique also shows promise as a means to detoxify photographic wastes, remove carbohydrate waste in the starch-processing industry, and to render pesticide wastes innocuous.

Irradiation Effects

The irradiation of metals in both fission and fusion reactors can affect their structural integrity. Alpha particles captured by aluminum, for example, readily capture elec-

trons from the aluminum to become helium atoms, which collect into helium gas bubbles that grow, diffuse, and coalesce, thereby weakening the metal and initiating crack formation. Scientists at the Idaho National Engineering Laboratory have discovered that helium bubbles diffuse at least 100 times faster at high temperatures through solid aluminum containing trace levels of certain metallic impurities than through pure aluminum. Thus, the impurities in the aluminum prevent the harmful buildup of helium bubbles. This finding provides valuable guidance to engineers who must select materials for reactors.

Sonic Cooling

Basic research on thermoacoustic-based refrigeration techniques, that is, sonic cooling, at Los Alamos National Laboratory led to three concepts for potentially practical and commercial applications. The Space Thermoacoustic Refrigerator, built at the United States Naval Postgraduate School and based on Los Alamos research, was flown on a 1992 flight of the space shuttle *Discovery*. This refrigerator is being evaluated as a refrigeration concept for use in space vehicles.

The second concept, the “sonic compressor,” uses sound to compress a refrigerant and can work with nonchlorofluorocarbon refrigerants that will not affect the Earth’s stratospheric ozone layer. A CRADA has been signed by Los Alamos National Laboratory and Tektronix, Incorporated, of Beaverton, Oregon, to develop and miniaturize a thermoacoustically driven pulse-tube refrigerator for cooling superconducting electronics. Sonic compression uses no moving parts, and the refrigerators are expected to have unprecedented high reliability, long life, and low manufacturing costs. This agreement also involves researchers at the National Institute of Standards and Technology who, together with Los Alamos researchers, invented the technology.

The third concept is a Two-Can Cooler for use in protecting electronic instrumentation from the high temperatures encountered at the bottom of geological exploration wells. This device has been designed and patented by Los Alamos.

Welding

Researchers at Oak Ridge National Laboratory developed a computational model that enables, for the first time, a three-dimensional analysis of heat transfer and liquid metal flow for welding processes. This modeling, which will provide information on how to optimize commercial weld-

ing processes, has shown that surface tension in the molten pool is the dominant force controlling the penetration of the weld. The computational algorithms developed for this model can be used to better understand heat and fluid flow during a wide range of materials processing conditions. CRADAs (under Defense Programs) have been established with General Motors to enhance the commercial utility of the model by improving the welding processes of lightweight materials for transportation applications, and with Concurrent Technologies to extend the software into an industrial tool for weld design.

Computational Materials Design

Scientists at Sandia National Laboratories-Livermore developed atomistic computer simulation codes to model the structure and properties of metals and alloys. This modeling potential is especially appropriate for metals such as aluminum and its alloys. Sandia’s expertise in atomistic modeling of small precipitates and in dynamic nucleation modeling were decisive factors in the signing of a CRADA with the Alcoa Technical Center in Alcoa Center, Pennsylvania, to combine the Sandia-developed computational tools with other codes used in the processing of aluminum alloys and aluminum products. This combination of computational tools will allow researchers to design new alloys, determine how they can be fabricated, and test their performance through computer simulation.

Product Innovations

Materials Sciences researchers received three 1992 R&D 100 awards for the following product innovations resulting from basic research programs (these awards are given annually by *Research and Development* magazine for the 100 most significant new technical achievements of the year):

1. A research team from Sandia National Laboratories-Albuquerque, the University of Illinois, and BIOSYM Technologies (a computer software company in San Diego) received an award for developing and commercializing a software system for predicting thermodynamic quantities and phase equilibria for polymer blends.
2. Oak Ridge researchers received an award for developing a method for producing hard-surface polymers using high energy ion beams. This processing improves polymer resistance to oxidation and chemical attack.

3. A research group at the Pacific Northwest Laboratory received an award for discovering and developing a glycine-nitrate process for synthesizing ceramic powders. Further work on this process has been carried out with support from the Office of Fossil Energy to develop lanthanum chromite powders for processing of ceramic ignitors.

Cooperative Research and Development Agreements

Materials Sciences basic research programs produced dozens of CRADAs in 1992, each of which will receive additional technology transfer support for the development phase from the Offices of Energy Research, Defense Programs, Energy Efficiency and Renewable Energy, and Fossil Energy. Industry funding for these jointly funded agreements totals \$45 million (to be spent typically over a 3-year period). Examples include the following:

Coatings for Automotive Fuel Lines

A 3-year CRADA between AC Rochester (General Motors) and the Pacific Northwest Laboratory will mimic the principles of biological hard-tissue formation to make hard coatings for components of an automobile fuel-delivery system. The original ideas and understanding of this subject were developed by Pacific Northwest Laboratory scientists with support from the Division of Materials Sciences. The Office of Energy Efficiency and Renewable Energy's Office of Industrial Technology, recognizing the potential of producing inexpensive hard coatings on complex shapes with no hazardous wastes, funded the adaption of this process to industrial needs. Under the CRADA, staff will regularly be exchanged between AC Rochester and the Pacific Northwest Laboratory, and both parties will commit \$300,000 per year.

Large Magnesium Oxide Single Crystals

A CRADA between Martin Marietta Energy Systems, Incorporated, and Commercial Crystal Laboratories of Naples, Florida, was initiated for 2 years to develop new techniques for growing large single crystals of magnesium oxide. The development phase, which is being funded with \$200,000 by each party through the Energy Research Technology Transfer Program, is based on the accomplishments of a long-term fundamental research effort supported by the Division of Materials Sciences at Oak Ridge. Commercial Crystal Laboratories is a small business that con-

tinues to be a principal supplier of specialty single crystals used as substrates for the deposition of thin films of high temperature superconductors and other materials. The only competing magnesium oxide-crystal-growth technology is foreign-based; Commercial Crystal Laboratories is the only domestic source for this increasingly important high-technology material.

New Methane Conversion Catalysts

Argonne National Laboratory and the Amoco Corporation signed a CRADA to conduct joint research aimed at testing the commercial utility of a new methane conversion catalyst developed by scientists at Argonne for the conversion of methane to higher petroleum products. The catalyst concept uses molecular sieve materials, such as zeolites, that contain metal sulfide clusters (for example, molybdenum sulfide) in their microscopic pores. This new technology will convert methane to other hydrocarbons at temperatures much lower than those of conventional processes. Several such materials synthesized by Argonne's Materials Sciences Division have demonstrated activity for converting methane (the principal constituent of natural gas) into higher-molecular-weight hydrocarbons in tests performed by Argonne's Chemical Technology Division.

Argonne's role in this CRADA will be to prepare, characterize, and supply to Amoco samples of the most active methane conversion catalysts synthesized to date. Amoco will confirm Argonne's methane activation experiments, quantify conversion efficiencies, perform catalyst tests under conditions not accessible at Argonne (for example, methane pressures greater than 1 atmosphere, or 101.325 kilopascals), and evaluate the apparent process thermodynamics to gauge the commercial feasibility of this new approach to methane activation based on Argonne's catalyst materials.

New Processing Methods for Elastomer Composites

A CRADA was signed between Sandia National Laboratories-Albuquerque and the Dow-Corning Corporation to develop new processing methods for strong elastic materials called silica-filled siloxane elastomer composites. These composites are used in building materials, seals, and electrical cables. Dow-Corning contacted Sandia because of its Materials Sciences-funded ceramics work on solution-polymerized silicates. Sandia and Dow-Corning will demonstrate a new synthesis route to composite materials that uses chemical, rather than mechanical, mixing

methods. The proposed research will closely track the approach of the Materials Sciences ceramics program.

The Defense Programs Technology Commercialization Initiative funds Sandia's contribution of \$250,000 per year. Dow-Corning is matching this support with in-house research.

Biocompatible Materials

Lawrence Berkeley Laboratory signed a CRADA with Glycomed, Incorporated, to design new biocompatible materials, such as surface coatings for vehicles in drug delivery systems, based on the adhesive properties of surface features of biological molecules. The polymeric materials that are produced will be marketed by Glycomed as anti-inflammatory agents. Further, the understanding of bioadhesion gained through this industry-laboratory cooperation may lead to the development of a new class of biocompatible materials for broad use in human implant devices.

Conducting Polymers

A CRADA between Brookhaven National Laboratory and the Moltech Corporation of Stony Brook, New York, was signed to develop new conducting and redox polymers. (Redox polymers use an oxidation-reduction process to store a charge, much like a battery electrode.)

This CRADA grew out of a basic research program begun in 1987 by the Division of Materials Sciences. The CRADA aims to, among other things, develop high-charge-density polymer batteries using redox polymers as the electrode and high-conductivity polymers as the electrolyte (Brookhaven holds a patent on the highest lithium-ion-conductivity polymer). Brookhaven will continue its research on the synthesis and characterization of high-conductivity polymers, and Moltech will use the new materials in making batteries and related components. The products will then be characterized at Brookhaven. Moltech was established in 1988 to develop applications for a number of materials technologies developed under the basic research program at Brookhaven, in collaboration with a research group at New York Polytechnic University.

High-Temperature Superconducting Magnetometer

A CRADA was signed by Lawrence Berkeley Laboratory and Conductus, Incorporated, to further develop a high-temperature, thin-film Superconducting Quantum Inter-

ference Device (SQUID) magnetometer. Based on thin-film, high-temperature superconductivity research, the first device was designed, fabricated, and tested by a team of Lawrence Berkeley researchers in collaboration with Conductus, and with support from the Department's Division of Materials Sciences and the California Competitive Technology Program. Applications for these new magnetometers, which are noninvasive detectors of very weak magnetic signals, include nondestructive testing, geophysics, and the detection of the faint magnetic signals from the human heart and brain. Conductus, Inc., began selling a SQUID system in March 1992, making the system one of the first applications of high-temperature superconductors to go on sale.

Chemical Sciences

Research supported by the Chemical Sciences Program focuses on the chemical properties of matter and the interactions among molecules, atoms, ions, and electrons. The long-term goal is to create new or improved processes for using and converting energy resources. Through chemical reaction studies, chemical sciences research ultimately affects such diverse areas as solar photochemical energy conversion, the production of fuels and chemicals from coal and other carbonaceous materials, catalysis, nuclear waste separations, the separation of metals from processing streams and low-grade mineral resources, combustion, and the detection and measurement of harmful byproducts of energy processes.

One major area of research in coal-related science focuses on understanding the structure and chemical reactivity of coal. Such an understanding, obtained by basic chemical research on a molecular level, will help develop new ways of transforming coal into synthetic gaseous or liquid fuels.

Combustion is another principal focus of the Chemical Sciences Program. Because world energy production is still overwhelmingly based on fossil fuels, controlling and reducing pollution largely depends on improving their combustion efficiency, which requires a broad, basic understanding of the complex processes of how these fuels are burned into their ultimate products—carbon dioxide and water vapor.

In such research areas as chemical catalysis, scientists seek to understand why certain materials uniquely promote specific chemical reactions. Such knowledge could be quickly exploited by industrial process designers. For example, knowledge of the interaction of methanol or heavy petroleum-derived oils with aluminosilicate zeolites has led to the efficient conversion of these chemicals

into new hydrocarbon species now used as high-octane fuels. Other research areas, such as photochemistry (the study of light-induced chemical reactions) to produce hydrogen from water decomposition, or energy directly from sunlight, may not find practical application for a number of years even though scientific advances are being made. In such research areas as atomic physics, the study of the interactions of atoms and electrons with plasmas may lead to the development of entirely new energy technologies.

Research Highlights

Heterogeneous Catalysis

Converting methane, the principal component of natural gas, into liquid form not only increases the safety of transporting it, but also greatly reduces the energy required to transport it, particularly from remote overseas sites. The Chemical Sciences Division supports a number of university projects that study the fundamental chemistries associated with more efficient utilization of methane. For example, new metal-coated alumina foam-monolith catalysts outperform other catalysts in converting methane into more usable chemical forms. The catalytic oxidation of methane has been hampered by the inability to obtain both high conversion rates and high selectivity of products, because as conversion increases, selectivity decreases as a result of carbon dioxide formation. These new catalysts have both high conversion rates and selectivity to the partial oxidation products (carbon monoxide and hydrogen), which can subsequently be used to produce diesel fuel or methanol.

The primary interest in this work has come from Royal Dutch Shell, whose pilot-plant studies have shown strong potential for directly using the carbon monoxide-hydrogen mixture as the feedstream for a methanol plant. Shell is constructing a plant in Malaysia to convert methane into diesel fuel and methanol through carbon monoxide and hydrogen intermediates. This advance in catalytic methane conversion resulted from indepth studies performed at the University of Minnesota on the fundamental chemistry associated with the coupling between homogeneous and heterogeneous oxidation reactions.

Combustion

Understanding combustion systems relies on a number of theories for estimating the rates of chemical reactions as a function of temperature. One such theory developed in the 1920s, RRKM theory (named for Rice, Ramsberger,

Kassel, and Marcus), remains the cornerstone of unimolecular dissociation theory, which has been incredibly useful in describing how large molecules break apart in the gas phase. But although RRKM theory provides a theoretical basis for unimolecular decay and describes the short-lived intermediate "transition state" with certain well-defined properties, in the 70 years since its proposal, no direct observation has been made of the transition state in any gas-phase chemical reaction. However, in an experimental tour de force, a Lawrence Berkeley scientist and Lawrence medalist and students observed a molecule in a transition state on the way to dissociation and measured directly the stepwise increase in dissociation rate as a function of internal energy, as predicted by RRKM theory. This confirmation has greatly strengthened the confidence of combustion modelers in RRKM theory. Professor R. Marcus of the California Institute of Technology was awarded the 1992 Nobel Prize in Chemistry in large part for his contributions to RRKM theory.

Photochemical Material Precursors

In fundamental research supported by the Chemical Sciences Division on material precursor chemistry and photochemistry, researchers successfully synthesized crystalline gallium arsenide particles with a narrow particle size distribution (20 to 50 angstroms in diameter). These particles exhibit properties that make them interesting as potential quantum dots. Quantum dot materials are of interest because of their unusual size-dependent electronic, optoelectronic, and photoredox properties. With normal materials these properties are composition-dependent. However, with quantum dots these properties are dependent not on the material composition but on the particle size of the particle. Thus, the ability to tune the particle size through synthesis is a primary goal.

The synthetic process uses the organometallic chemistry of arsenic and gallium to produce small colloidal gallium arsenide particles. With these types of semiconductors, the principal problem has been devising synthetic routes with sufficient selectivity to yield a clean product with a small-particle-size distribution. The recent advance has been in matching the organometallic precursors with the coordination power of the solvent to control the growth of the particles. The objective of continuing studies is to understand how both the absolute size and the size distribution can be controlled so that particles of any size can be made with a distribution of only a few angstroms. Such particles could form the basis for new nonlinear optics, optical computers, and solar photocatalysts.

Engineering and Geosciences

The objectives of engineering research are to improve knowledge of processes underlying current engineering practice, to expand the technical data base and understanding of fundamental engineering concepts, and to improve the ability to anticipate and solve engineering problems in energy technologies. Fundamental research is supported in both traditional engineering disciplines and interdisciplinary areas concerned especially with the analysis, control, and improvement of systems for materials processing and those for advanced manufacturing and heat and fluid transport. At present, three more specific disciplines are receiving high priority: mechanical sciences, including fluid mechanics, heat transfer, solid mechanics, and structures; systems and control sciences, including systems analysis and control and instrumentation; and engineering analysis, including engineering data collection and compilation and analysis of nonlinear and nonequilibrium systems.

Engineering Research Highlights

Fundamental Robotics Research for the Human Genome Program

In addition to some new discoveries, past results of basic engineering research produced some unexpected applications in 1992. For example, a fundamental problem facing autonomous robotic systems is the reconciliation and integration of data from multiple sensors needed for decision-making—so-called sensor fusion. Sensor fusion is accomplished by techniques such as neural networks and fuzzy logic. Recently, research on these techniques supported by the Engineering Research Program at the Center for Engineering Systems of Advanced Technology (CESAR) inspired a group at Oak Ridge National Laboratory to create novel and highly effective software for picking out coding regions in human deoxyribonucleic acid (DNA). (The Oak Ridge group included some CESAR-ORNL staff and was partially supported by DOE's Office of Health and Environmental Research.) The software package, Gene Recognition and Assembly Internet Link (GRAIL), can reliably and quickly find 90 percent of exons of 100 bases or more in length using a personal computer, rather than a supercomputer. Preliminary results have narrowed the location of the gene responsible for Huntington's disease, reducing considerably the effort needed to identify the gene itself. GRAIL is now in use by over 300 genome research laboratories worldwide.

New Automobile Illumination System

Ordinary principles of conventional optics aim to get as good an image of a given object as possible. However, high-efficiency collection of solar energy requires other criteria that are not satisfied by conventionally designed optical instruments. In particular, none of the rays that enter the collector must ever reemerge. To attain that, a researcher at the University of Chicago, with support from the Engineering Research Program, has formulated and studied new optical principles, the so-called nonimaging optics.

A particularly novel application of these ideas is a new design of automobile taillights. Hewlett-Packard joined the Ford Motor Company in implementing arrays of light-emitting diodes as an illumination source for taillights, replacing the customary incandescent lamps. The success of the new illumination system rests on the effectiveness of running a nonimaging collector in reverse, which makes it act as an efficient light beam-forming device rather than a solar-power collection system.

The first car to use this new system was the 1992 Ford Thunderbird. The system is energy efficient and durable, and its compact design offers new freedom to car body designers because the nonimaging optics can be packaged as thin, flat panels.

Fiber Ring Laser Technology

Research by a University of Maryland professor, supported by the Engineering Research Program, on pulse propagation in inhomogeneous optical waveguides has been applied by AT&T to the development of a fiber ring laser that can produce 50-picosecond solution pulses suitable for long-distance communications.

Fiber ring lasers using erbium-doped fibers as amplifiers have attracted much attention recently because of their simple structures and the rapid progress in erbium-doped fiber technology. Because erbium-doped fiber amplifiers have a bandwidth of about 30 nanometers, very short pulses can be generated. A fiber ring laser proposed by AT&T was greatly improved by adding both a saturable absorber and a frequency limiter so that the laser would remain stable.

This general area of research, soliton propagation in optical fibers, is now generally accepted as the method of choice for transoceanic communication at bit rates exceeding 5 gigabytes per second. The recent work at the University of Maryland has already impacted laser design efforts by two groups at AT&T: one seeking to produce 50-picosecond pulses for long-distance communication

applications, the other seeking subpicosecond pulses for switching and solid-state probing experiments. The simulation codes for pulse propagation in optical fibers developed at the University of Maryland are also being used by researchers at the Naval Research Laboratory in Washington, D.C.; Harvard University in Cambridge, Massachusetts; the Massachusetts Institute of Technology; and several other universities.

Geosciences Research Highlights

Viable energy technologies for the future must be efficient, economical, and environmentally sound. Although the particular details of future energy technologies are uncertain, it is clear these technologies will consume energy and mineral resources and generate technological wastes. The Earth not only is the source for these resources, but also is the host for the wastes generated.

Geosciences research provides fundamental knowledge about the processes that transport, modify, concentrate, and emplace the Earth's energy and mineral resources and anthropogenic energy byproducts. Hence, geosciences research is directed toward a fundamental understanding of the dynamics of the Earth's systems processes.

To accomplish this task, the Geosciences Research Program supports basic research, from the atomic to the continental scale, to define and quantify fundamental Earth processes; to support the development and application of predictive physical, mechanical, and chemical models; and to develop and utilize geophysical and geochemical methodologies to test these models. The program supports a multidisciplinary community of scientists broadly spread among universities, national laboratories, other DOE divisions, and other Federal agencies with technological applications for industry, the environment, and other branches of science.

Earth Dynamics

Earth scientists at Lawrence Livermore National Laboratory, in cooperation with the U.S. Geological Survey, have processed earthquake data to obtain fundamental, three-dimensional images of the tectonic and volcanic processes of the Earth's structure beneath northern California. These images reveal low-velocity regions, identified as magma bodies, associated with known volcanic fields (the Clear Lake and Mt. Lassen systems) and a steeply dipping oceanic plate beneath the southern Cascade Mountains and northern Great Valley to depths as great as 250 kilometers. In a separate study, researchers at Stanford University investigated the faulting and stress release by

earthquakes in producing oil-field reservoirs and developed a model explaining the coupling among seismicity, pore fluid pressure, and rock deformation. These results provide a fundamental basis for understanding the interaction among tectonics, volcanics, and earthquakes on both a regional and local scale, as well as the foundation for applied research in resource evaluation, such as finding and extracting fossil fuels or geothermal energy, and seismic hazards, such as predicting and measuring earthquakes.

Modeling

Based in part on laboratory evidence and Earth dynamic studies, Earth scientists, supported by the Geosciences Research Program, have shown that fractures and rock systems have a mechanical behavior that is strongly coupled to the movement of fluids through the system, or its hydrology. The ROCMAS simulator computer code, developed at Lawrence Berkeley Laboratory for modeling the complex thermal, hydrologic and mechanical processes in geologic systems, was verified with field experiments using fluid injection tests. These tests were performed in cooperation with the University of Luleå, Sweden, with partial support from the Office of Civilian Radioactive Waste Management. The ROCMAS code can simulate the effects of natural processes and geoengineering projects, including geothermal reservoir development, efficient recovery of oil and gas from in-situ reservoirs, and the prediction of thermal stress and hydrologic transport in nuclear waste disposal. ROCMAS will also be used in the design and construction of deep Earth Laboratories.

The chemical interaction of fluids is another strongly coupled process in Earth systems, but much of the fundamental chemistry of these fluids is ill-defined for the Earth's crustal conditions. For example, aluminum is the third most abundant element in the Earth's crust and plays a major role in determining the chemistry of brines in sedimentary basins and geothermal systems. However, the geochemistry of aluminum has been poorly characterized because of its exceedingly low solubilities, extremely sluggish dissolution and precipitation rates, and tendency to form complex species.

To help characterize the geochemistry of aluminum, scientists at Oak Ridge National Laboratory, with support from both the Basic Energy Sciences Program and the Office of Geothermal Energy, determined the thermodynamic properties of Al^{3+} and $\text{Al}(\text{OH})_4^-$ and the solubility of gibbsite under naturally occurring conditions. In separate studies, the dissociation and stability constants of hydrocarbons and oxalic acid were measured at high temperature, pressure, and salinity, covering the range of con-

ditions encountered by fluids in the Earth's crust responsible for the formation, reaction, transportation, and migration of gas, oil, and metals. These measurements were incorporated into major computer codes designed to model fluid-rock interactions. Such models are critical to understanding the fundamental effects of dissolution and precipitation of subsurface aluminum salts during petroleum migration, geothermal fluid flow, and nuclear waste storage.

Researchers at Johns Hopkins University are investigating the oxidation-reduction reactions at the mineral-fluid interface that are responsible for the mobility of metals in solution. The experimental work has focused on a combination of electron microscopy techniques that have allowed researchers to determine the oxidation state and the adsorption mechanism of sheet silicates, surface precipitates, and so forth, on the atomic level. The results were then used to understand and develop a model for recording mineral-fluid reactions in naturally occurring copper deposits. It also has direct applications to metals transport in the environment and in nuclear waste repositories.

Model Testing

The Earth's crustal structure and distribution of energy and mineral resources can be better understood by combining the models described in the preceding section with experimental studies of Earth's solid-phase deposits and fluid distributions. The following specific techniques have been developed to extract this geologic record and to help test the predictive capabilities of the theoretical models.

In a pioneering study of the isotopic geochemistry of noble gases in natural gas traps, scientists at the University of California-Berkeley have identified two isotopically distinct groups of gases in the Alberta gas field. These two groups, which are identifiable over distances of 300 to 500 kilometers, are geographically separated and correlated with the major nitrogen component of the gas field. The analysis of the results confirms a direct involvement of the Precambrian Basement rock in the transport processes governing the formation of structural gas traps and the importance of large-scale vertical and horizontal transport of gases to localized gas traps. This learning provides valuable new insight into the factors that control the formation of gas reservoirs in the Earth's crust.

In a separate study, this same group, in collaboration with scientists from Argonne National Laboratory, developed a technique that can chemically analyze a suite of elements by injecting as little as 10 microliters (10 cubic millimeters) of fluid into minerals. This new, ultrasensitive

technique greatly increases the ability to investigate fluid-mineral interactions that have occurred either in the geologic past or under conditions of high temperature and pressure. This technique has yielded important information about the sources of fluid and interactions in ancient hydrothermal systems. For example, analyses of microscopic fluid inclusions from the hydrothermal lead-fluorite-barite deposits at Hansonburg, New Mexico, which were deposited 30 to 65 million years ago, indicate an originally meteoric fluid that acquired chlorine and sulfate from marine evaporites, acquired argon-40 and lead from aquifer and basement rocks with significant ages, and deposited the lead and fluorite without phase separation (boiling). The extreme sensitivity and high spatial resolution of this technique may also offer promise in materials synthesis and characterization of ceramics, where high temperatures are employed.

To better define the time scale of Earth processes, scientists at Los Alamos National Laboratory have developed a new methodology for high-precision mass spectrometric dating. This new technique has improved the resolution of uranium and thorium series dating of the last 500,000 years from ± 10 percent to less than 1 percent, which will allow high-resolution examination of the global climate change record and other environmental changes. When combined with the stable carbon and oxygen isotopic record of carbonate samples from Cold Water Cave in northeast Iowa, this high-precision record compiled by Los Alamos defines midcontinental climatic change in the 1,000-to 10,000-year (before present) range. These results can now be incorporated into the data base needed to test the feedback mechanisms and atmospheric linkages used in global climate change models.

Energy Biosciences

As the use of plants and microorganisms for the production of various resource materials and for bioprocessing applications increases, so does the need for fundamental biological research dealing with such organisms. Such knowledge will underpin new biotechnologies, and is crucial to ensure not only that they serve the needs of society, but do so without unexpected risks to both human health and the environment. Plants and microbes can be used as renewable resources for fuel and other fossil resource substitutes, as vehicles for restoring previously disrupted environmental sites (bioremediation), and for carrying out reactions that conserve energy compared to

chemical conversions, such as for more efficiently converting biomass into ethanol.

The Energy Biosciences Program addresses fundamental biological mechanisms and principles of plants and microorganisms not studied in the health field, including organisms' growth, survival, adaptation, maintenance, morphological and biochemical characteristics, and energy utilization. Its mission is to provide bases for new and improved energy-related biotechnologies. One of the major objectives of the Energy Biosciences Program is to probe the enormous capabilities of these organisms to carry out biochemical conversions.

For centuries, cultures around the world have depended on plants and microbes for their food, fiber, medicine, fuel, and a wide variety of other uses. But these earlier uses resulted from empirical findings, without the benefit of the powerful research approaches now available. These approaches, such as molecular biology, analytical chemistry, and computational analysis, have opened entirely new horizons and opportunities through biotechnology.

Research Highlights

Transfer of Biosynthetic Capabilities Into Higher Plants

Using the substantial background technology developed for the transfer and expression of genetic information, researchers at the Plant Research Laboratory of Michigan State University demonstrated the feasibility of installing into a higher plant, in this case *Arabidopsis*, the capability to biosynthetically produce polyhydroxybutyrate, a biodegradable plastic. The origin of the genetic material encoding the biosynthetic pathway for the plastic was the bacterium *Acaligenes eutrophus*. This work demonstrated that it is possible to perform a genetic transfer of a gene complex from a bacterium to a higher plant. In addition, the expression of the genes in the plant was not easily distinguishable from the form of polymer bodies found in the original bacterium (Figure 11-10).

This work relates to energy matters because of its future prospects for using plants as renewable replacements for petroleum products. In this case, using plants as a source to produce a biodegradable plastic would not only displace petroleum use, but also would provide a product that is easily disposed of because it is readily broken down by microbes. Industry's appreciation of using plants as resources for new products is growing, and this research could set a pattern for such future efforts. Although the concept of using plants as product feedstocks needs fur-

11-10. Biosynthetic production of polyhydroxybutyrate, a biodegradable plastic.

ther development—in particular, the system needs to be developed in larger plants with appropriate concentrating mechanisms to make the products cost-effective—the results of the work with *Arabidopsis* are encouraging.

Microbial Mechanism of Glucose Uptake

The fermentative bacterium *Zymomonas mobilis* very efficiently converts glucose into ethanol because the organism's cells acquire very little energy for each molecule of glucose metabolized; therefore, the organism must convert a large quantity of glucose into ethanol to sustain growth. Researchers, supported by the Energy Biosciences Division, at the University of Nebraska are studying the metabolic control of carbon flow through *Z. mobilis*. Recent results have shown that a type of nonenergy-requiring uptake system, not previously described in bacteria, is found in *Z. mobilis*. This system, a passive glucose facilitator, instead of the more typical energy-requiring active transport system, appears to be intimately associated with the overall control of the glucose-to-ethanol pathway. The glucose facilitator is likely an adaptation to the low energy yield realized from glucose metabolism. Such research may ultimately help enhance the production of ethanol by elucidating a novel mechanism of glucose uptake and conversion.

Genetic Control and Differentiation

One of the most complex biological processes is the differentiation of tissues. Although there have been considerable advances in understanding these processes in

organisms such as *Drosophila* (a genus of flies), only now are plants beginning to be better understood in this context. In recent studies of floral differentiation in plants, researchers at the California Institute of Technology have gained insights into genetic interactions associated with transitions from vegetative to floral growth. Mutants in *Arabidopsis* (a genus of plants in the mustard family) have been used for these studies. Understanding these differentiation processes in plants may help increase their overall productivity, which in turn could increase their contribution as renewable resources.

Advanced Energy Projects

The Division of Advanced Energy Projects (AEP) includes the AEP Program and the Small Business Innovation Research Program, which is described later in this chapter. The AEP Program explores the feasibility of novel, energy-related concepts that evolve from advances in basic research. These concepts are typically at an early stage of scientific definition and therefore beyond the scope of ongoing applied research or technology development programs. AEP also supports high-risk, exploratory concepts that do not readily fit into a program area but could have applications that may span several scientific disciplines or technical areas, and provides a mechanism for converting such basic research findings into applications that eventually could impact the Nation's energy economy. AEP does not support ongoing, evolutionary research or large-scale demonstration projects.

Projects are supported for a specified period of time, typically 3 years. In 1992, the average annual funding level per project was \$320,000, and the average funding period was slightly less than 36 months. It is expected that, after AEP support, each concept will be sufficiently developed and promising to attract further funding from other sources to realize its full potential.

Research Highlights

Plastics From Vegetable Oils

In a plants-to-plastics AEP-supported project at Rensselaer Polytechnic Institute, oils derived from agricultural products were used as the feedstock material. The oils were epoxidized with acetic acid and hydrogen peroxide to bond additional oxygen atoms to groups of carbon atoms. Next, nontoxic catalysts were added. The resulting substance can then be applied to surfaces and converted into plastic

under ultraviolet light. This process eliminates a number of steps in plastics coatings and offers energy efficiency as well, and the plastics may be biodegradable. A divergent set of industries has expressed interest in applying such plastic surfaces to their products, ranging from beverage cans to printing for the blind.

Novel Radioactive Waste Treatment Method

Researchers at Argonne National Laboratory developed a two-phase, aqueous extraction method for treating radioactive waste. The separation process involves selective partitioning of either solutes or colloid-size particles, depending on the waste being treated, between two immiscible aqueous phases. By coupling physical separation with chemical processing, this process significantly reduces the volume of mixed wastes generated from the dissolution recovery process, and some chemical species dissolved in water can be recovered. These results have attracted follow-on funding from the Department's Office of Environmental Restoration and Waste Management to develop this technology for the treatment of uranium-contaminated soils.

Applied Mathematical Sciences

The mission of the Applied Mathematical Sciences (AMS) Program is to improve DOE's ability to solve critical scientific and engineering problems through research on and application of advanced mathematical, computational, and computer sciences. Managed by the Office of Scientific Computing (OSC), the AMS Program is divided into two ongoing activities: mathematical, computational, and computer sciences research and advanced computation, communications research, and associated activities. The AMS Program is DOE's major contributor to the High Performance Computing and Communications Initiative (HPCCI), and closely coordinates with HPCCI programs of other agencies and DOE's overall participation in the initiative. (HPCCI is described in detail in "Computational Science".)

Scientific advances traditionally have depended on experiments for data and on theory for understanding. However, the enormous power of the modern supercomputer, coupled with the concomitant increased ability to perform realistic modeling of physical problems, has introduced a third, equally important component: computational science, which is a tool both for studying the effects of control parameters on physical systems through computer

simulations and for extending theoretical understanding and interpreting experimental data.

Mathematical, Computational, and Computer Sciences Research

The primary objective of mathematical, computational, and computer sciences research is to advance understanding of the fundamental concepts of mathematics, statistics, and computer science. These concepts underlie the complex mathematical models of key physical processes encountered in research and development (R&D) programs on advanced computer architectures—concepts that may lead to new approaches to applying supercomputers. Research on the major elements of this subprogram—high-performance computer systems, advanced software tools and algorithms, and basic research and human resources (including initiatives in education as well as appropriate basic research in mathematics, computational, and computer science)—is carried out at national laboratories, universities, and private research institutions. All these areas emphasize new parallel-multiprocessor architectures. Parallel multiprocessor architectures employ a large number of computer processors working together to find the answers to large scientific problems. These computers typically have hundreds or thousands of processors; as a comparison, today's Cray C-90 supercomputer has 16 processors.

The mathematical sciences research activity also has established over the last few years several computing research facilities at Sandia-Albuquerque, Argonne, Los Alamos, Oak Ridge, the University of Illinois, and the Courant Institute at New York University to support the exploration of new concepts in large-scale scientific computing. The facilities at Los Alamos and Oak Ridge, which also serve as collaborative consortia, are designated High Performance Computing Research Centers as part of HPCCI and in response to the High Performance Computing Act of 1991. Collaborative consortia are joint national laboratory, university, and industrial collaborations focused on specific scientific and technical goals. They were mandated in the High Performance Computing Act.

Advanced Computation, Communications Research, and Associated Activities

Advanced computation, communications research, and associated activities provide the high-performance computing resources and high-capacity network access required by Office of Energy Research investigators, as well as research on leading-edge communications technologies and associated information management activities. The

Department's National Energy Research Supercomputer Center (NERSC), formerly the Magnetic Fusion Energy Computational Center, now operates a Cray Y-MP (8 processors with 64 million words of memory and 256 million words in a solid-state disk), the serial #1 Cray-2 (4 processors with 62 million words of memory), a Cray-2 (4 processors with 128 million words of memory), the unique 8-processor Cray-2 (128 million words of memory), and a 16-processor Cray C-90, which was delivered in 1992. NERSC, which uses the UNICOS operating system, has a storage capacity of more than three terabytes (million million bytes).

The Supercomputer Computations Research Institute at Florida State University, funded by the Office of Energy Research at the direction of Congress in 1985, now operates a Cray Y-MP (4 processors with 32 million words of memory), an associated solid-state disk (128 million words of memory), and more than 24 billion bytes of mass storage using UNICOS. The Institute also has a 65,536-node Connection Machine (CM-2) from Thinking Machines, Inc., with 2 billion bytes of central memory and 2,000 64-bit, floating-point processors. These facilities also are available to Office of Energy Research investigators.

Access to these resources and to Office of Energy Research science facilities, in general, is provided through the Energy Sciences Network (ESnet), a 19-node backbone nationwide data communications computer network with international connections to Europe and Japan. ESnet provides information exchange and dissemination among scientific collaborators throughout all Office of Energy Research programs and widespread access to existing Office of Energy Research supercomputer facilities. ESnet currently operates at T1 speed (1.54 million bytes per second). Current plans are to begin upgrades to T3 (45 million bytes per second) and higher speeds in 1994.

Computational Science

The Office of Scientific Computing also is responsible for the DOE component of the President's 5-year HPCCI. The goals of HPCCI are to extend U.S. technological leadership in high-performance computing and communications, improve U.S. productivity and industrial competitiveness, and speed the pace of technological innovation. HPCCI will accomplish these goals by solving important scientific and technological challenges through a vigorous R&D effort; reducing the financial risk of industrial R&D; improving HPCCI technologies through increased cooperation among government, industry, and universities; supporting the HPCCI's underlying research, network, and computational infrastructures; and strengthening the U.S.

human resource base to meet the needs of industry, universities, and government.

The major emphases of DOE's HPCCI component are to:

1. Support computational Grand Challenge problems, based on DOE programmatic missions, by applying advanced software technology, developing new algorithms that effectively use new computer systems, and establishing High Performance Computing Research Centers funded or staffed by DOE
2. Undertake R&D on digital communications at speeds approaching 1 gigabit per second to enhance ESNet and its integration into the National Research and Education Network
3. Carry out fundamental research and encourage research participation by young scientists and engineers and science education at all levels
4. Promote R&D on new high-performance computer systems and evaluate their potential

The hallmark of DOE's HPCCI component is building on the underlying philosophy of the AMS Program: collaboration of interdisciplinary groups of scientists and engineers at the national laboratories and universities and in industry. This philosophy was followed in 1991 by initiating the following projects, and continued in 1992 and 1993: Computer Design of Catalysts (Sandia National Laboratories-Albuquerque), Parallel Algorithms for Quantum Chemistry (Sandia National Laboratories-Livermore), Lattice Gas Algorithms for Porous Flow Phenomena (Los Alamos), Computational Materials Sciences (Oak Ridge, Brookhaven, and Ames), and Environmental Remediation Computations (Oak Ridge, Brookhaven, Rice University, the State University of New York at Stony Brook, and South Carolina University).

Research Highlights

DOE also initiated projects in the areas of object-oriented data base technology, applied to and cofunded with the Superconducting Super Collider; large spatial data bases; mass storage systems, in conjunction with several private firms via the newly developed CRADA between NERSC and these firms; distributed computing technologies; and software environments. DOE projects in the areas of computational catalysis studies, quantum chemistry and drug design, and molecular and materials sciences in cooperation with private firms have produced significant new understanding of enzyme chemistry and the binding of anticancer drugs to DNA in tumor cells.

In addition, DOE installed a Cray C-90 supercomputer system at NERSC as part of its base program activities to provide state-of-the-art (class VII) computer technology in its access program to fill the need for available high-performance computer resources until the Department can introduce a massively parallel computer in a full-production environment in late 1995. In the area of gigabit research, DOE has been concentrating on optimizing and enabling packetization of workstation video and multimedia capabilities, on advancing visualization and other user applications for gigabit network capabilities, and on advancing local area network capabilities to handle data requirements of massively parallel systems for mass storage access, wide area network interfaces, and other purposes. DOE has initiated several projects in conjunction with the Advanced Research Projects Agency (ARPA; formerly the Defense Advanced Research Projects Agency) and held joint coordinated, program reviews of these projects with ARPA during 1993.

In the area of education, DOE has continued several excellent programs in its base program, including the DOE High School Science Student Honors Program; the Southwest Indian Polytechnic Institute, which is designed to improve the computer literacy of American Indians; and teachers' workshops to train teachers in high-performance computing and communications technology and use and to train them to conduct such workshops themselves. Some of these workshops are cosponsored by Cray Research, Inc., which donated a supercomputer (the National Education Supercomputer at NERSC) to support this effort. Recent highlights include the following:

1. The NERSC education coordinator received a DOE Public Service Award for her contributions to DOE's education efforts.
2. DOE initiated an Adventures in Supercomputing program at three DOE laboratories to capture and cultivate the interest of women, minority, and disadvantaged precollege students in science, mathematics, and computing in conjunction with more than 20 high schools in 1992. This program includes summer teacher fellowships at DOE laboratories and is coordinated with many other high school programs, such as the New Mexico Supercomputer Challenge, the Alabama Precollege Supercomputing and SuperQuest Programs, and the Colorado State computational science program.
3. DOE has drafted and made available on the ESnet, and on the interagency interim National Research and Education Network, a syllabus for teaching computational science at the graduate level. This

work involved 24 authors from 10 disciplines. It is in electronic format, incorporating graphics utilizing Macintosh and IBM RS 6000 technologies and allows one to execute examples on IBM, Intel, Cray Research Inc., Thinking Machines, Inc., and Kendall Square systems. It is maintained at Vanderbilt University, where it is available over the Internet.

Grand Challenge Computational Projects

DOE conducted an interagency panel evaluation of proposals for Grand Challenge computational research projects important to the Department's mission. These projects were selected by a peer review panel that included non-HPCCI program managers and other HPCCI agency participants and was chaired by a NASA program manager. The six Grand Challenge research areas selected, which are cofunded by other DOE programs and industrial partners and include DOE laboratory, university, industry, and other HPCCI agency participation, are as follows:

1. *Computational Chemistry*, to effectively parallelize important chemistry codes to study critical problems in the chemistry of halohydrocarbons, the chemistry on and in clay minerals, and the rational design of biodegradative enzymes for environmental remediation and potential energy sources. This project is cofunded by four industrial partners and the DOE Chemical Sciences Program.
2. *Computational Structural Biology*, for research in computational methods of protein folding, parallel programming environments for biology, profile analysis for structural comparison and prediction, predictive models of cellular organelles, and large-scale sequence analysis. This project is cofunded by the DOE Health and Environmental Research program, a National Science Foundation (NSF) Science and Technology Center, a biomedical industrial firm, and a university foundation.
3. *Mathematical Combustion Modeling*, to develop algorithms for high-resolution discretization techniques with adaptive methods, to enable effective parallelization of resulting combustion models, and to make these models useful to private sector and government scientists and engineers. This project is cofunded by the AMS Program and DOE national laboratory internal R&D funds.
4. *Elementary Particle Physics Lattice Gauge Calculations*, on massively parallel machines, to improve the quenched-quark approximations by developing algorithms that use full-scale high-performance com-

puting (HPC) systems and to further refine the Standard Model (a simplified picture of the physical world at its most fundamental level). This project is cofunded by DOE and NSF high energy physics programs.

5. *Parallel Algorithms*, for efficient use of HPC systems to simulate flow through permeable media, especially oil-flow simulations. This work is based on reservoir models developed at the University of Texas that are widely used by the oil industry, and is cofunded by DOE's Environmental Sciences Program, an industry consortium of 26 companies, 2 computer vendors, NSF, and the State of Texas.
6. *Computational Research in Fusion Energy*, to develop a Numerical Tokamak Project, that is, integrated particle and fluid plasma models on massively parallel machines, as part of a multidisciplinary study of tokamak core fluctuations. The measure of success will be the degree to which the observed scaling of fluctuation-driven transport can be predicted. The project is cofunded by the DOE fusion energy program and is an important component of the implementation of the fusion program required by the Energy Policy Act of 1992.

Mass Storage System of the Future

A cooperative research and development agreement was signed between the National Energy Research Supercomputer Center and six private sector firms to begin research on the mass storage system of the future for the National Storage Laboratory. This new storage system will allow rapid access to the enormous data sets generated by modern computational and experimental science. DOE scientists are defining the requirements and necessary performance parameters for this systems.

Heterogeneous Computer Networks

Heterogeneous computer networks—systems ranging from workstations to supercomputers linked together by high-speed networks—are becoming commonplace in high-performance computing. Until recently, each computing resource on the network remained a separate unit; however, a software package called PVM (Parallel Virtual Machine), originally developed at Oak Ridge, now enables a network of heterogeneous parallel and serial computers to operate as a unified computational resource. Such flexibility allows different subtasks of a heterogeneous application to exploit particular strengths of individual machines on the network. Twenty to thirty institutions

worldwide are now using PVM to write and run truly heterogeneous programs that use multiple computer systems to perform applications such as modeling chemical systems.

High Performance Computing Research Centers

DOE created two High Performance Computing Research Centers (HPCRCs) in 1992, one at Los Alamos and one at Oak Ridge. The centers are funded through industrial and university partnerships, as well as cofunding from other DOE programs.

These HPCRCs will

1. Conduct research on all four of DOE's HPCCI program components
2. Operate full-scale models of massively parallel HPC system prototypes installed at these HPCRCs during 1992 (a Thinking Machines, Inc., CM5 computer at Los Alamos, and an Intel Corporation Paragon at Oak Ridge)
3. Perform computational research on global climate research, environmental groundwater transport modeling, and materials sciences calculations
4. Serve as an intellectual center to evaluate the suitability of advanced computer architectures for Grand Challenge class problems, as well as to provide high-performance computer system resources for computational research for the selected energy-related Grand Challenge research projects

The HPCRC at Los Alamos also is a partner in an NSF-sponsored Science and Technology Consortium.

Small Business Innovation Research Program

The Small Business Innovation Research (SBIR) Program is designed to foster private sector commercialization of technology developed through Federal R&D, increase small business participation in Federal R&D, stimulate technological innovation, and foster and encourage participation by women-owned and socially and economically disadvantaged small business concerns.

The Department's SBIR Program supports energy-related R&D activities in accordance with the Small Business Innovation Development Act of 1982 (Public Law 97-219), as amended (Public Law 99-443). On October

28, 1992, the program was reauthorized until the year 2000 by the Small Business Research and Development Enhancement Act of 1992 (Public Law 102-564). The DOE SBIR Program, which is administered by the Office of Energy Research, focuses on high-quality R&D projects on advanced concepts relevant to important energy-related scientific or engineering problems.

The 11 Federal agencies subject to Public Law 97-219 spent 1.25 percent of their extramural research or R&D funds on SBIR projects in each year from 1986 through 1992. Public Law 102-564 increases the percentage to 1.5 percent in 1993-1994, 2.0 percent in 1995-1996, and 2.5 percent thereafter. The 1992 and 1993 SBIR budgets for DOE were 42.6 million and 49.7 million, respectively. As per Public Law 102-564, the 1993 budget includes, for the first time, the Department's programs in environmental restoration and waste management and in arms control and nonproliferation.

The program is implemented in three phases. Phase I determines the scientific or technical merit and feasibility of ideas proposed for investigation. This phase lasts about 6 months, and awards have been limited to \$50,000 from 1983 to 1992. The phase I award limit was raised to \$75,000 in 1993. Phase II is the principal research or R&D effort. Qualified projects have received as much as \$500,000 for periods of up to 2 years. Historically, one-third to one-half of the phase I projects have proceeded successfully into phase II. In phase III, small businesses either carry out the commercial application of the R&D effort with non-Federal funding, or they may be awarded non-SBIR Federal contracts for products or services required by the Government.

The Department issues SBIR Program solicitations annually, with R&D opportunities provided each year in about 40 topical areas. These topics have included basic energy sciences, health and environmental research, high energy and nuclear physics, magnetic fusion energy, energy efficiency and renewable energy, nuclear energy, fossil energy, environmental restoration and waste management, and arms control and nonproliferation.

In 1993, the Department selected 171 projects for phase I awards out of 1,999 grant applications submitted. From the 198 projects that received phase I funding in 1992, the Department selected 70 for phase II awards in 1993, with average funding of about \$500,000 per project for a 2-year period.

In 1992, the Department selected 198 projects for phase I awards out of 1,534 grant applications submitted. From the 173 projects that received phase I funding in 1991, the Department selected 66 for phase II awards in 1992, with average funding of about \$495,000 per project for a

2-year period. From 1983 to 1992, the Department received 11,944 phase I applications and made 1,354 phase I awards and 503 phase II awards. From the first five cycles of awards (phase II projects completed between 1986 and 1990), DOE SBIR winners have already received more than \$220 million in phase III funding, which is about 50 percent more than the SBIR support they were given. This number is expected to grow significantly in the next few years.

In all cases, selections were based on expert review of the scientific and technical merit of the applications. Competition among the various topics is keen, and each application competes against all others, regardless of topic area. The quality of SBIR projects appears to be comparable to that of all other R&D supported by the Department.

As a measure of the program's success, 10 DOE SBIR projects have received R&D 100 awards from *Research and Development* magazine, which selects the 100 most significant technical products each year. In addition, 5 DOE awardees were chosen among the 500 fastest growing American private companies in the December 1991 issue of *Inc. Magazine*, based on their growth in sales.

Because so many small companies lack the business skills necessary for rapid commercialization of their technologies, the Department has instituted a special training project, called a commercialization assistance project, that is supported with non-SBIR funds. For the past 3 years, successful phase II awardees have been given individual assistance in developing a business plan and in preparing sound and concise visual materials describing a business opportunity that could be presented to potential sponsors. The culmination of the project was a series of presentations by the SBIR awardees to the sponsors, which included representatives from large corporations and venture capital firms. As a result of participating in the 1991 project, these companies have already received more than \$5.5 million for commercializing their SBIR research; and more than 40 percent of the firms that completed the project have received further funding. A new commercialization assistance project was completed in the fall of 1993.

The Department continues to receive reports of successful phase III projects. An outstanding example is Biolog, Inc., of Hayward, California, a 1989 phase II recipient that also won a 1991 R&D 100 award. The company has developed kits that help characterize and identify bacteria that could be useful for the biodegradation of pollutants around weapons manufacturing sites. The Biolog test kit for bacteria identification is fast, easy to use, and relatively inexpensive. The strength of the system lies in its potential for identifying *all* bacteria. In fact, Biolog's kits are the first to identify a significant number of environ-

mental bacteria. The company has already sold more than \$2.8 million worth of the kits to hospitals, universities, cosmetic and pharmaceutical companies, the U.S. Department of Agriculture, the Food and Drug Administration, the Centers for Disease Control, and other Government agencies and private companies.

BIOLOGICAL AND ENVIRONMENTAL RESEARCH

The Biological and Environmental Research Program at the Office of Health and Environmental Research (OHER) has two main missions: (1) to develop the knowledge base necessary to identify, understand, and anticipate the long-term health and environmental consequences of energy use and development and (2) to use the Department's unique scientific and technological capabilities to solve major scientific problems in medicine, biology, and the environment. The program uses the unique capabilities and facilities of the national laboratories and supports university faculty and students and investigators from industry and other Federal agencies conducting research aimed at resolving health and environmental issues while strengthening U.S. energy security and economic growth.

Health Research Program

The Health Research Program, part of the overall BER Program, has two major themes:

1. *Studies of biological changes associated with exposure to radiation and chemicals:* These studies focus on developing new quantitative data, principles, models, and instrumentation to reduce the uncertainty in assessing the health risks associated with exposure of humans to energy-related radiation and chemicals.
2. *Biotechnology-related research efforts:* This research includes programs in structural biology, the human genome, and medical applications that are crucial for advancing the U.S. biotechnology industry. It includes studying the relationship between molecular structure and function of macromolecules such as proteins; developing the resources and technologies needed to construct chromosome maps and determine the sequence of the 3 billion DNA subunits comprising the genetic code of the 24 differ-

ent human chromosomes; and interfacing developments in molecular biology and structural biology with nuclear technology and imaging sciences to create new medical applications for the study, diagnosis, and treatment of disease.

Specific research highlights are listed under "Health Research Highlights."

Health Effects Research

The Health Effects Research Program conducts research to provide a scientific basis for improved risk estimates of the long-term human health effects associated with exposure to low-level radiation, including radon, and chemicals. This program also provides a scientific foundation for understanding and anticipating the long-term health consequences of energy development and use, as well as the impact of DOE operations on human health. The program's multidisciplinary approach includes research with experimental biological systems, ranging from molecules to intact organisms, to (1) identify the mutagenic and carcinogenic consequences of exposures; (2) characterize the biological, biochemical, and molecular mechanisms for carcinogenesis and for DNA damage and repair; (3) describe the initial radiological and chemical events that occur after exposures; and (4) develop new measurement concepts and dosimetry to detect, measure, and characterize radiological and chemical hazards.

Radiation and Chemical Effects

Epidemiological studies of atom bomb survivors, radium dial painters, uranium miners, and nuclear shipyard workers have provided important empirical data for estimating the upper limits of risk for selected radiation exposure conditions in which people were exposed to high doses and dose rates of radiation. However, studies of suitable populations are limited in both availability of people for study and experimental control. Preliminary reports from international epidemiological studies of people who were exposed to indoor radon at low doses and dose rates suggest that conclusive estimates of the risks of lung cancer for these radiation exposures are not likely to be obtained. Thus, more information is needed to reduce uncertainties in extrapolating health risks from exposures at high doses and high dose rates to the low doses and low dose rates that occur in the general population.

The inherent limitations in human epidemiological research, coupled with the need to understand the biological basis of effects in living systems that are caused by

the byproducts of energy operations, require more controlled studies with experimental systems. Such studies involve three closely related objectives. The first is to use dose-response studies in laboratory animals to provide quantitative estimates of incidences of late somatic effects, including cancer and life shortening, that result from chronic, low-level exposure to ionizing radiation. These dose-response studies also provide detailed estimates of radiogenic gene and chromosomal mutations. The second objective is to understand basic mechanisms in radiation-induced delayed somatic and genetic effects in mammalian cells, tissues, and organs and in the intact organism. This objective is also intended to understand how total dose, dose rate, mode of exposure, repair activity, and other variables modify responses to radiation. The third objective is to improve the extrapolation of experimental data for predicting health risks in humans. Understanding the mechanisms of and genetic changes in cancer development is important in identifying potential environmental carcinogens, in estimating the cancer risk from exposure to energy-related agents, and in developing better indicators for early diagnosis of cancer.

For example, since 1992, DOE-funded scientists at the Inhalation Toxicology Research Institute and the University of New Mexico have been characterizing specific changes that occur during the development of radiation-induced lung cancer. In a prospective study, sputum samples and bronchial brushings are being collected from former uranium miners who may be at increased risk for developing lung cancer. These samples are being examined for cellular and molecular changes associated with lung tumors to identify patients who may have preclinical tumors, or individuals who may be at increased risk for subsequent tumor development due to the presence of pretumorigenic changes in isolated lung cells.

In parallel studies at the Inhalation Toxicology Research Institute, lung cells are being isolated from animals exposed to radiation similar to that received by uranium miners and examined for the appearance of cellular or molecular markers for tumorigenic or pretumorigenic cells. These studies should improve the understanding of the differences and similarities of lung cancer development in people and experimental animals, thereby improving the accuracy of risk estimates extrapolated from animal data to people. They may also improve the understanding of early events during lung cancer development and provide tools for early diagnosis of lung cancer or for identifying individuals who may be at an increased risk of developing lung cancer.

One goal of the Health Effects Research Program is to develop the knowledge base necessary to determine if the

risks of lung cancer in people who are exposed to energy-related radiation or chemicals can be estimated by using data from studies of animals. A collaborative study begun in 1993 among Pacific Northwest Laboratory, Argonne National Laboratory, and the Inhalation Toxicology Research Institute is aimed at improving the extrapolation of cancer risks among species and eventually from animal data to people. This study involves the development of improved tools for analyzing carcinogenesis data and comparing experimental carcinogenesis data from radiation carcinogenesis studies in different strains and species of animals.

Cellular and Molecular Bases of Health Effects

To improve the estimation and understanding of risks to human health from exposure to toxic agents, research is supported to determine the mechanisms by which radiation and energy-related chemicals produce biological damage; how such damage is repaired and transmitted into observable end effects, such as mutations and cancer; and to identify early markers for exposure, injury, or disease. Understanding and comparing these effects and processes for similar exposures of animals and people to radiation or chemicals provides a basis for extrapolating health risks in people from animal data.

DOE supports research of the mutagenic and carcinogenic effects of energy-related radiation and chemicals. Specific studies include molecular analyses of spontaneous and exposure-induced mutations in people and in cultured human cells. They also include characterization of the genes involved in carcinogenesis and growth regulation and analyses of chromosome abnormalities, common toxicant-induced genetic alterations that have been observed in many heritable diseases and in cancer.

Scientists at Lawrence Berkeley Laboratory continue to develop and improve molecular cytogenetic techniques available to both research scientists and clinicians for detecting and analyzing chromosome abnormalities. New techniques, using different colors of fluorescent molecules, to label DNA probes and new microscopic and analytical techniques have been developed to aid in the detection and identification of such changes. These advances improve methods of screening for prenatal and neonatal genetic abnormalities, localization of cancer genes, and diagnosis and prognosis of solid tumors.

During the past several years, scientists at Lawrence Livermore National Laboratory have developed a rapid and simple method of detecting chromosome abnormalities in cells, using fluorescence in-situ hybridization. The

method is called chromosome painting. Chromosome "paints" have been used to demonstrate that in all healthy men, some sperm have chromosome abnormalities. If one of these abnormal sperm fertilizes an ovum, these abnormalities could lead to spontaneous abortion, a malformed embryo, or a newborn with a genetic disease. This study will be useful in understanding how abnormal sperm develop and in identifying genetic and environmental risk factors for paternally transmitted chromosome abnormalities.

Scientists have long used traditional cytogenetic analyses, such as scoring for dicentric chromosomes, as biological indicators of radiation exposure. Lawrence Livermore National Laboratory scientists, working in collaboration with scientists at the Radiation Effects Research Foundation in Hiroshima, are using chromosome paints to analyze blood samples from atomic bomb survivors for dicentric chromosomes. Chromosome painting is about 10 times faster than standard cytogenetic analysis, and it is a useful and efficient means of estimating radiation doses among the large numbers of atomic bomb survivors still under study. It is also useful for estimating doses in other people exposed to agents that induce chromosome aberrations. Finally, Lawrence Livermore National Laboratory scientists, in collaboration with scientists from Pacific Northwest Laboratory, are developing the reagents necessary for painting specific mouse and rat chromosomes. These mouse- and rat-chromosome-painting probes should be useful in studies of the induction and persistence of chromosome alterations in laboratory experiments involving low-dose, long-term exposures to chemicals or radiation.

DOE supports research to identify, isolate, and characterize the genes that control the repair of DNA damage in human cells. This research should help define, at the molecular level, the intrinsic biological limitations to repairing damage. It may also aid in assessing the heterogeneity of radiation or chemical sensitivity in the human population and in identifying individuals at increased or reduced risk for exposure-induced adverse health effects. Augmenting the efficiency of repair genes through molecular mechanisms is possible and may be useful therapeutically in repair-deficient people. Research is being conducted with cultured cells isolated from individuals with repair disorders and with animal models of repair deficiency to delineate the role of DNA repair and DNA repair genes in normal development and aging and in mutagenesis and carcinogenesis. Scientists at the Laboratory of Radiobiology and Environmental Health at the University of California-San Francisco have identified a gene that appears to be involved in the human disease ataxia-telangiectasia

(AT). AT is a genetic disease involving repair deficiencies and is associated with an increased likelihood of developing some types of cancer and an unusual sensitivity to ionizing radiation. Because carriers of the AT gene may have an increased risk of cancer, understanding the genetic basis of AT and determining the possible role of the AT gene in cancer predisposition are important.

Scientists at Lawrence Livermore National Laboratory are involved in an international effort to identify genes that control and encode the proteins in the human DNA repair system responsible for nucleotide excision repair, a type of repair in which damaged bases are recognized and removed. They cloned a human repair gene, ERCC4, that is involved in the repair of ultraviolet-light-induced DNA damage, and perhaps in the xeroderma pigmentosum, a heritable human DNA repair disorder.

Physical and Chemical Processes

This program investigates the basic physical and chemical processes initiated by the interaction of ionizing radiation with matter. The emphasis is on identifying those processes that might be most relevant for understanding the basic mechanisms of biological action. For this reason, the program is enhancing research to attain fundamental knowledge of the physical and chemical processes involved in the interactions of energy-related agents, both ionizing radiation and chemical, with biologically relevant materials. Interaction products such as ionizations, excitations, and radicals are considered the initial determining factors in the ultimate biological response. Spatial and temporal distributions of interaction products in biologically relevant molecules such as DNA, proteins, lipids, and other structures in the natural environment of the cell are investigated to determine where and how the initial biologically significant lesions are formed. The program is multidisciplinary and attempts to integrate the fields of physics, chemistry, and biology to develop biophysical models for predicting the health risks associated with energy-related pollutants.

Instrumentation Research

The main objective of this program is to develop state-of-the-art instrument and measurement technology and methodologies for detecting and studying the consequences of energy-related pollutants such as radiation and chemicals on the environment and human health. The program emphasizes developing radiation detectors to better characterize radiation sources, enable more accurate and precise measurements of exposure to all forms of ionizing radia-

tion, and provide more reliable and scientifically defensible estimates of radiation doses. The natural radiation background and physical mechanisms of radiation transport are also studied. These studies are important, for example, in understanding the transport and behavior of radon in the indoor environment and in determining the exposure from radon and its progeny. Quality control and assessment of radon dosimetry and personal dosimetry are conducted under this program.

Over the years, this program has received more than 40 R&D 100 awards. Among the standards tools developed under this program are single-atom detection techniques, using ultraspecific laser spectroscopy, and remote sensors for pollutants, using fiber optic cables. Current research seeks to improve the specificity of laser-based techniques by combining them with other instrumentation, such as mass spectrometers, and to extend the available techniques to handle more complex sample materials. This program also focuses on research that will contribute to structural biology studies using synchrotron x-ray sources and to medical applications of nuclear technology. Instrumentation and techniques are being developed, with emphasis on extremely sensitive methodologies that can measure biological damage at the cellular and subcellular level.

Radon Research

The DOE Radon Research Program is a multidisciplinary effort that includes research on several aspects of the subject, ranging from the source of radon in the environment to the health risks associated with the exposure of humans to radon. A goal of the program is to provide data that reduce scientific uncertainties associated with estimating and controlling the human health risks from exposure to low levels of indoor radon. The program also identifies future research priorities necessary to better define and minimize the risks from exposure to radon and to provide data that can be used as a basis for making better radon policy decisions based on science. The program meets this goal by supporting physical, biological, and environmental studies, such as measuring the concentration and transport of radon in the environment, modeling the entry and transport of radon indoors, and elucidating the physics and chemistry of radon decay products. A substantial number of studies are under way to define exposure-dose relationships, identify the critical lung cells at risk and the biomarkers of exposure and effects, and to understand the fundamental mechanisms of radon and copollutant carcinogenesis. The DOE program has stimulated an ongoing national debate on Federal radon policies.

The Radon Research Program has produced information that has been used to determine that health risks to humans from exposures to radon in homes are less than from comparable exposures in mines. It has shown that certain building and geologic characteristics allow areas with higher radon levels to be targeted for study. The studies have also shown that short-term radon measurements are potentially misleading and that cellular repair may attenuate damage from low-level radon exposures. These findings, together with other information, have been used to suggest a need for reevaluating federally mandated radon policies.

Biotechnology Research

The importance of biotechnologies to the health of the Nation's industrial and scientific base is increasingly recognized as these technologies spread from applications in biology, medicine, and the pharmaceutical industry to other sectors, including energy (biomass production), environment (bioremediation of waste), agriculture, materials science (biomaterials), and genetic engineering (genetically introduced chemical modification of engineered enzymes for biocatalysis). The Biotechnology Research Program, which provides the scientific focus for DOE's biotechnology activities, also expects to exploit the advances in understanding the structure, organization, and function of genes for assessing the human risk from radiation and other environmental factors. New technologies developing at the boundaries between nuclear medicine, instrumentation development, and molecular biology are fostering the development of a new generation of medical applications for the study, diagnosis, and treatment of human diseases.

Human Genome

The DOE Human Genome Program (HGP) supports the Department's traditional missions of evaluating the health effects of radiation and other energy-related agents and of employing DOE resources for beneficial applications in biology, medicine, and the environment. The HGP grew out of the Department's long-term commitment to understanding the mutagenic effects of radiation exposure and the need for improved capabilities to detect heritable and somatic cell genetic damage. The HGP's information and resources are actively applied to the Health Effects Program, particularly in the areas of radiation and chemical effects and medical applications, and they will provide much of the molecular basis for estimating risks from in-

dividual exposures to energy-related radiation and chemicals.

The National Institutes of Health (NIH) and the Department of Energy are the only two Federal agencies with formally identified human genome programs; together, they comprise the Nation's Human Genome Project. Research activities are coordinated through a memorandum of understanding that establishes a joint DOE-NIH advisory subcommittee.

The DOE HGP stresses mapping, developing sequencing technologies and instrumentation, and improving methodologies for storing, accessing, and manipulating the vast amounts of genetic and sequence data that the program will yield. The HGP also emphasizes studies on the ethical, legal, and social issues arising from the program, particularly in the area of privacy and confidentiality of genetic information. Crosscutting these goals is the very important, departmentwide imperative to foster and promote science education activities; for this, the multidisciplinary HGP is ideal because it brings together so many disparate disciplines, technologies, and sciences. The NIH effort, which has a different scope, emphasizes the genetics of disease-related genes in both human and nonhuman systems in addition to addressing the ethical, legal, and social issues of this joint project.

In the area of constructing the genetic maps, researchers at Human Genome Centers at Lawrence Livermore National Laboratory and Los Alamos National Laboratory have essentially finished the physical maps of chromosomes 19 and 16, respectively. These resources have already proved valuable for localizing several disease genes, among them the myotonic dystrophy gene on chromosome 19q13.3 and the Batten disease gene chromosome 16p. Similarly, work supported by DOE at Baylor University College of Medicine (Houston) has recently identified two genes associated with two forms of mental retardation. DOE researchers have developed and made broadly available several resources, such as libraries representing chromosome-specific human DNA clone sets, libraries of microdissected chromosome fragments, and fluorescence in-situ hybridization technology, as well as robotic instrumentation to manage and manipulate these resources.

In the area of sequencing technologies, DOE-sponsored researchers continue to pursue multiple approaches. Improvements of standard technologies include primer walking, which exploits a new way of building the 18-base primer required to initiate the DNA synthesis, and various approaches for speeding up the critical sequencing gel electrophoresis step. Among the new approaches being pursued is sequencing by hybridization, in which an

unknown DNA sequence is reconstructed from reactions with known short oligonucleotide probes. An additional sequencing approach being developed involves single-molecule sequencing with detection by laser-induced fluorescence and rapid analysis of DNA sequences by mass spectrometry.

In the critically important area of computational support (informatics) for the HGP, continuing efforts on chromosome map assembly, data base development, sequence analysis, and laboratory automation are resulting in rapid progress. DOE is the lead agency in managing the Genome Database at Johns Hopkins University, the primary community data base for human chromosomal mapping data. This resource is available to any researcher in the world who is connected to the Internet. DOE-sponsored scientists continue to contribute to the DNA sequence data base GenBank, first built at Los Alamos National Laboratory and now managed by the National Library of Medicine. DOE is also supporting the development of additional methodologies to simplify the simultaneous access to multiple related data bases for biomedical scientists.

Structural Biology

The main objective of DOE's structural biology program is to develop and facilitate the use of DOE national user facilities by the biomedical and biotechnology research communities. These facilities include neutron beam and synchrotron light sources, as well as other unique instrumentation and associated computing resources. Such facilities are required for the investigation of complex biological structures—such as proteins and other macromolecules, chromosomes, and viruses—that cannot be fully characterized with conventional laboratory instrumentation. Facilities are being equipped with upgraded and new beam lines, state-of-the-art experimental stations, sample preparation laboratories, and computing resources and staffed with people who are highly trained in structural biology techniques.

A smaller component of the program involves exploiting the unique opportunities to advance biological science at existing facilities and developing new instrumentation and techniques to take full advantage of the increased capabilities of the new synchrotron light sources at Lawrence Berkeley and Argonne National Laboratories and, eventually, the powerful Advanced Neutron Source planned for Oak Ridge National Laboratory.

The structural data obtained at these DOE facilities, together with the techniques of modern molecular biology, will help elucidate the relationships between structure and function in biological systems. Increased

understanding of these relationships is critical to the Department's missions in energy development and environmental protection, ranging from improved use of sunlight for biomass fuel production to development of enzymes capable of detoxifying hazardous wastes. Use of the unique structural biology tools by researchers in academic laboratories and in industry serves as a significant form of technology transfer from the national laboratories by providing the foundation for a wide spectrum of advances in the biomedical sciences and in biotechnology.

Medical Applications

The Office of Health and Environmental Research's Medical Applications and Biophysical Research Division uses statutory authorities and fulfills congressional directions with respect to the development of beneficial applications of nuclear and other energy-related technologies for medical diagnosis and treatment. The Medical Applications Program carries out comprehensive research aimed at the use of radioisotopes for medical purposes, development of medical imaging instrumentation, chemical synthesis of radiopharmaceutical agents, and preclinical and clinical feasibility studies. The general thrust of the nuclear medicine research program is to develop new nuclear medicine procedures by producing new radionuclides, radiolabeling new biologically active agents, and advancing instrumentation. In addition, advances in molecular nuclear medicine and monoclonal antibodies are used to improve the methodology for detecting and treating disease.

The Department's nuclear medicine research has been at the forefront of important medical discoveries, and has led to the widespread use of nuclear technology in modern clinical and laboratory medicine. In fact, the entire field of nuclear medicine owes its existence to work growing out of research conducted by DOE and its predecessors. Through innovation and use of the latest developments in molecular biology, molecular medicine, and imaging science, new avenues of diagnosis and treatment are opened. The development of advanced technologies for clinical diagnosis, such as positron emission tomography (PET), coronary angiography using synchrotron radiation, and magnetoencephalography for brain functioning, have all been made possible largely through access to the unique facilities and skills in DOE-supported laboratories, including nuclear reactors, charged-particle accelerators and nuclear instrumentation, and modern computer technology. Moreover, the skills of DOE scientists have been essential catalysts in transferring nuclear technologies to medical applications. The Department maintains contact

and relationships with the National Institutes of Health, professional medical societies, and the private sector to expedite use of new developments in clinical settings.

Using PET, scientists are studying how neurochemical systems in normal and diseased brains differ in their response to external stimuli such as mental challenge, motor tasks, and therapeutic drugs. This information is providing the basis for understanding the molecular mechanisms that contribute to the development and progression of disease. In the case of schizophrenia, PET is providing an objective biochemical measurement that will help understand why some patients respond to medication and others do not. Further, this approach can also be directed toward examining the biochemical mechanisms responsible for the side effects frequently associated with antipsychotic drug administration, and then used to design more effective drugs while expediting their introduction into the practice of health care and their approval for widespread use (Figure 11-11).

Radiopharmaceuticals are radioactively labeled medicinal compounds that concentrate in certain body organs; they can then be imaged with sensitive radiation detectors to make the body's internal organs visible to medical diagnosticians. They are developed and used in metabolic, diagnostic, and therapeutic studies. Changes in the spatial and temporal distributions of the labeled substances allow diagnosis to be made without invasive procedures such as biopsies. Recent efforts in molecular nuclear medicine have been aimed at imaging molecular biology in vivo to define the specific receptor targets for in-vivo diagnosis and treatment of disease.

Though recent radiopharmaceutical research and molecular medicine emphasize studies of cancer diagnosis and therapy and brain and heart metabolism, they also contribute to diagnosis and therapy involving other organs. DOE's molecular nuclear medicine research activity also evaluates methods for studying, diagnosing, and treating diseases such as cardiopulmonary disease, mental disorders, and metabolic disorders. For example, modern molecular biology techniques to genetically engineer tumor-cell-surface-receptor-specific antibodies and highly selective molecular probes for neuroreceptors in the brain allow disease processes to be studied at their fundamental molecular basis.

DOE is leading a major effort to develop boron neutron capture therapy for the treatment of brain tumors and melanomas. Boron neutron capture therapy is based on the fact that the reaction of an isotope of boron with neutrons releases radiation in a highly localized volume. When used with boron compounds that selectively concentrate in tumors, this technique may make it possible to deliver

11-11. A special medical imaging method, positron emission tomography (PET), is being used at Brookhaven National Laboratory to track neurochemical changes that occur in the brain as a result of antipsychotic medication. PET can be used to directly study the effect of therapeutic drugs in patients with schizophrenia and other neurological and psychiatric disorders.

therapeutic doses of radiation to the tumor cells with minimal effects to adjacent healthy tissue. Ongoing laboratory research is aimed at developing appropriate boron-containing compounds, preparing facilities for neutron irradiation, and creating the scientific data necessary for approval by the Food and Drug Administration and recognition by the medical community as a safe and effective therapeutic modality. Initial trials to evaluate the safety of a new boron compound, boronophenylalanine (BPA), for human use have been initiated.

DOE instrumentation research emphasizes the development of advanced medical imaging systems for rapid, noninvasive studies of brain and heart functioning. Researchers at the Lawrence Berkeley Laboratory developed new radiation detector materials for improved imaging of the very short-lived isotopes used in PET, and designs for detector modules were prepared for ultrahigh-resolution

imaging of tracer compounds in the brain. True, three-dimensional PET systems have been constructed at the University of Pennsylvania and Massachusetts General Hospital that allow simultaneous imaging of whole organs, rather than a series of discontinuous slices. PET is now being used to study the consequences of drug addiction to the brain.

Researchers at Los Alamos National Laboratory have also continued their progress in the use of biomagnetism (magnetoencephalography) for rapid, three-dimensional imaging of brain functioning. They have established the principles for a new, large array of relatively inexpensive sensors and have organized collaboration with the private sector to transfer the technology. Magnetoencephalography measurements can now be combined with magnetic resonance imaging images to compare structure to function.

Environmental Research

The goal of DOE's Environmental Research Program is to provide the foundation for understanding the effects of energy-related activities on the environment. Research approaches integrate studies on human-induced and natural processes to provide resolution for energy-related environmental problems. Elements of the program also address national and international concerns regarding global environmental change. In meeting these goals, the research directly supports the Energy Policy Act of 1992.

To achieve program objectives, comprehensive research in atmospheric, terrestrial, subsurface, oceanic, and economic systems is conducted in different regions of the world. For maximum effectiveness in terms of both cost and science, most of the research is organized into multidisciplinary, multi-institutional programs. The programs cover all environmental aspects of the physical, chemical, social, and biological sciences. A strong educational program is maintained to develop future scientists for the global issues facing humankind.

Environmental Processes and Effects

Research into environmental processes and effects includes defining the transport, transformation, and fate of energy byproducts in atmospheric, terrestrial, subsurface, and marine systems and also identifying the major routes and rates of transfer of these byproducts through physical and biological pathways. Recent program initiatives address the role of molecular biology in understanding oceanic, terrestrial, and subsurface ecosystem responses and op-

portunities for biotechnology developments. Natural and energy-related stresses are studied from the subcellular level to the ecosystem level to determine the rates and mechanisms by which populations and ecosystems disturbed by energy activities adapt or react to these stresses. The following are some of the categories of research conducted.

Atmospheric Chemistry and Dynamics

Research in the atmospheric sciences concentrates on the transport, deposition, transformation, and climatological effects of energy-related emissions to the atmosphere. Its primary objective is to provide DOE with the knowledge of atmospheric processes that is essential for energy policy analysis and strategic planning. The research includes a combination of field, laboratory, and modeling activities. Large-scale chemical-meteorological models, which are applied for data interpretation as well as for policy analysis, are primary products of these efforts. The atmospheric chemistry emphasis is placed on the aqueous-phase processes, such as in-cloud chemical reactions, precipitation scavenging, and midlatitude stratospheric and tropospheric ozone. (Stratospheric ozone protects the Earth from the Sun's ultraviolet radiation; tropospheric ozone ("smog") occurs near urban centers and is considered an air pollutant). Studies of complex-terrain meteorology deal with the significant complications in atmospheric behavior introduced by terrain; these complications must be characterized and represented properly for reliable air quality and emergency preparedness models.

Ocean Margins

The goal of ocean margins research is to determine whether continental shelves remove quantitatively significant amounts of carbon dioxide (CO₂) from the atmosphere and isolate them through burial in sediments or export to the interior ocean. The research is directed toward quantifying the mechanisms and processes by which CO₂ is assimilated, transported, and transformed in the coastal ocean and toward defining ocean margin sources and sinks in global biogeochemical cycles. Thus, this research directly supports global change objectives as well as environmental process studies.

Subsurface Science and Environmental Radon

Subsurface Science

The Subsurface Science Program conducts basic research on the physical, chemical, and microbiological mechanisms

that control the fate of chemical mixtures and on the natural heterogeneity of the subsurface biosphere. The program is recognized internationally for pioneering multidisciplinary research, cooperatively with industry and others, on the microbiology of the deep-subsurface biosphere. The research contributes to resolving long-term DOE environmental restoration problems and questions relating to industrial biotechnology and energy supply. A technology transfer program involving industry and others has been operating since 1987, and it has made significant discoveries concerning the presence and activity of microbial communities at depth.

Environmental Radon

Environmental research efforts within the Radon Research Program are directed toward characterizing the availability and emanation potential of radon within soils, defining the environmental variables that control radon transport within soils and its movement into homes, developing predictive models to link environmental transport with indoor radon levels, and identifying areas that may be affected by elevated levels of indoor radon.

Ecosystem Research

The Program for Ecosystem Research focuses on understanding the biological processes of homeostasis and genetic selection and the ecological processes of succession that control organismic responses to natural and human-

induced environmental changes. Such knowledge is useful in understanding ecosystem adjustments to changes in the environment and how the adjustments might be used to enhance ecosystem sustainability. Research activities include how organisms in ecosystems respond to environmental changes and variations, how the responses are controlled, how the responses and controls can be measured, and how the organismic responses are integrated across organizational levels.

Global Change

The mission of the Department's Global Change Research Program (Figure 11-12) is to estimate the future levels and rates of increase of atmospheric carbon dioxide and other energy-related emissions and to understand and predict the potential effects of emissions on climate and biota. This information is required to provide a scientific underpinning for energy policy options aimed at preventing, mitigating, or adapting to increasing greenhouse gas concentrations and to global environmental change. The program will elucidate the processes controlling the global carbon cycle and predict future levels of atmospheric CO₂, determine how changes in concentrations of greenhouse gases may change the Earth's radiation balance; acquire the data and develop the models to determine how changes in the Earth's radiation balance may change climate at global and regional scales and to predict rates of climate change; develop the scientific methodology to determine

11-12. The principal objective of DOE's Global Change Research Program is to improve the predictability of climate change models. The DOE Atmospheric Radiation Measurement (ARM) Program addresses the most important scientific uncertainty in climate change: the role of clouds. ARM data and analysis will greatly improve climate change models.

and quantify the combined effect of climate change and greenhouse gas concentrations on the biosphere; and develop essential elements of integrated assessments to link policy needs and research products. The program's principal objective is to improve rapidly the Nation's capability to predict regional and global climate change. The following are some of the categories of research conducted.

Climate Modeling and Computer Hardware, Advanced Mathematics, and Model Physics

Climate Modeling

To develop the tools for accurately predicting CO₂- and greenhouse-gas-induced global and regional climate change, DOE supports a core research program on climate change modeling, with attention to the coupled climate system of atmosphere, ocean, biosphere, and cryosphere. A key element of this program is support of the program for climate model diagnosis and intercomparison (including the international general circulation model intercomparison studies), whose work includes the study of clouds and the regional and interannual climate sensitivity to greenhouse gases. Climate model development also improves linkage of biosphere-climate and ocean-climate feedbacks for representing land-atmosphere-ocean energy and water flux.

Computer Hardware, Advanced Mathematics, and Model Physics Program

The objective of the Computer Hardware, Advanced Mathematics, and Model Physics Program is to accelerate and improve predictions of the future responses of global and regional climates to the increasing atmospheric concentrations of CO₂ and other greenhouse gases. Developing an advanced climate model will require computers capable of increasing throughput by a factor of at least 10,000 over 1990 technology, mathematical formulations and software that utilize the extensive parallelism of the emerging generations of computers, and improved algorithms that have been more thoroughly verified, using more comprehensive sets of field observations than ever before.

Quantitative Links and Atmospheric Radiation Measurement

Quantitative Links

To link quantitatively the predicted global and regional climate changes with observed changes in measurable Earth system properties (such as temperature and precipitation),

DOE maintains a core research program to develop the prehistoric, historical, and modern data sets essential for model verification and climate change detection.

Atmospheric Radiation Measurement

The objectives of the Atmospheric Radiation Measurement (ARM) Program are to describe quantitatively the radiation balance from the Earth's surface to the top of the atmosphere and determine the atmospheric characteristics responsible for this balance, improve the parameterization of the formation and evolution of clouds in climate models, create an experimental test-bed for testing process models used in general circulation models, and to support satellite ground truth measurements. ARM research involves a network of ground-based remote-sensing instruments along with campaign studies (high-intensity measurement periods) with aircraft and tethered platforms. ARM focuses on quantitative links between greenhouse gases and climate change and examines climate feedbacks and energy fluxes in the coupled land-atmosphere-ocean system. In addition, the research examines atmospheric cycling and transformation of radiatively and chemically important trace species.

Carbon Cycle and Vegetation Research

The Global Carbon Cycle Program supports measurement and modeling activities to estimate changes in the physical, chemical, and biological processes that control sources and sinks of CO₂. Measurements of CO₂ fluxes between atmosphere, biosphere, and land and ocean surfaces and of carbon cycling within the terrestrial biosphere and the oceans are necessary to predict atmospheric CO₂ change in relation to releases from burning fossil fuel and deforestation. DOE's unique research on plant responses to various CO₂ concentrations is focusing increased attention on plant carbon metabolism, specifically to address basic biological mechanisms that affect direction, rate, and magnitude of CO₂ fluxes and biotic responses to CO₂ enrichment. The program's scope includes work on the carbon dynamics of terrestrial, aquatic, and marine environments to quantify the sources and sink strengths of vegetation, soil, and sediments for carbon.

Ocean Research

The Oceans Research Program supports a global survey of CO₂ in the ocean and various studies to improve ocean circulation models used for climate research. The research involves integrated laboratory, observational, and

modeling studies to understand mixing, transport processes, and carbon cycling in the ocean and the exchange of heat and carbon between the ocean and the atmosphere. As part of the U.S. Global Change Research Program, the DOE Oceans Research Program is focused on central questions about the rates of carbon and heat transport in the ocean and changes in the oceanic CO₂ reservoir. It is a critical component of the biogeochemical and ocean dynamics elements of the U.S. Global Change Research Program.

National Institute of Global Environmental Change

The National Institute of Global Environmental Change was created by Congress in 1989 to support DOE's Global Change Research Program, primarily by providing funding for scientists in the academic community. Proposals submitted to the institute through its regional centers primarily address the high-priority areas in DOE's Global Change Research Program. The institute's goal for allocation of funding is 75 percent for scientific aspects of global environmental change, 20 percent for research on policy options and strategies, and 5 percent for educational efforts. The University of California at Davis operates the institute for DOE under a cooperative agreement. The National Institute of Global Environmental Change consists of five regional centers (Northeastern Center, at Harvard University; Midwestern Center, at Indiana University, Indianapolis; Southeastern Center, at the University of Alabama, Tuscaloosa; Southcentral Center, at Tulane, University of Louisiana, New Orleans; and Western Center, cohosted by the University of California at Davis and the University of California at Irvine). Projects supported through the institute span a range of priorities in the U.S. Global Change Research Program.

Integrated Assessment

DOE initiated the Economics/Integrated Assessment Program in 1993 to provide support for integrated assessment activities and a better link between the U.S. Global Change Research Program and policy choices. The Economics/Integrated Assessment Program funded research primarily in two areas: (1) technology and diffusion and (2) greenhouse gas indices. A recent comparison of selected climate change economics models showed that perhaps the most important input to the models was the amount of new technology predicted to be invented and exploited. The research program is investigating, for example, how

to reconcile the fact that much new energy technology saves money with the fact that consumers still fail to choose it. In addition, as actions are taken to reduce greenhouse gases, the research on greenhouse gas indices will allow more efficient solutions by providing a framework for ameliorating the damages caused by the various greenhouse gases during different periods.

Health Research Highlights

Advances in Disease Research

Scientists at Oak Ridge National Laboratory have isolated disease genes from mice that may provide insights into corresponding diseases in humans. In an experiment on polycystic kidney disease, one of the most commonly inherited disorder in humans, a mouse mutant with polycystic kidney disease resembling the disease in humans was identified. The causative mouse gene was isolated and used to isolate the corresponding human gene. Diagnostic DNA reagents are being prepared to determine if and how this gene is altered in human families with polycystic kidney disease. In other studies at Oak Ridge, a mouse gene for grizzled coat color has been cloned and shown to be related not only to coat color but also to a number of adverse health effects, including pronounced obesity, diabetes, and tumors. The obesity-associated diabetes in these mice is remarkably similar to noninsulin-dependent diabetes in obese humans. This is the first gene for genetic obesity to be cloned, and it provides an opportunity for investigating in an animal model this common and debilitating human disorder.

Sickle-cell is a blood-borne illness that afflicts up to 100,000 African Americans. By inserting a human gene for sickling hemoglobin, biologists at Oak Ridge National Laboratory have genetically engineered a line of mice that exhibit sickle-cell disease in much the same way humans do. These mice should serve as improved models for testing preventive drug therapy for sickle-cell disease, leading eventually to human trials for prevention of sickle-cell disease.

Scientists at Lawrence Berkeley Laboratory have developed a rapid cell culture assay to distinguish normal human breast epithelial cells from their malignant counterpart. By placing normal or malignant breast cells in culture dishes containing basement membrane material, the extracellular matrix that surrounds cells in vivo has been shown to direct the morphogenesis and differentia-

tion of rodent breast tissue. In this environment, normal breast cells had the appearance of normal breast tissue seen *in vivo*. In contrast, malignant breast cells placed in the same environment were able to proliferate, but did not appear normal. This represents the first time that normal human breast cells in culture have been shown to recapitulate aspects of normal breast cell growth and differentiation. These observations will further understanding of early events involved in the development of human breast tumors. Understanding the mechanisms involved in the development of human breast cancer increases the accuracy of estimates or predictions of breast cancer risk from exposure to energy-related radiations and chemicals.

Radon Research

Radon, in homes and at work, is the largest single source of radiation exposure to the general public and is estimated to be a significant cause of lung cancer in the U.S. population, particularly among nonsmokers. Scientists at Lawrence Berkeley Laboratory have estimated that between 50,000 and 100,000 U.S. homes have indoor radon levels in excess of radiation exposure limits for nuclear workers. The laboratory has initiated a joint research effort with the U.S. Environmental Protection Agency and the U.S. Geological Survey to identify those areas of the United States with the most high-radon-level homes, using results from indoor radon monitoring and local physical factors, such as soil type and radium content, geology, meteorology, and housing characteristics. These efforts will help rapidly identify and remediate homes posing the greatest risk from radon exposure.

Exposures of lung cells to radiation from indoor radon occur at very low dose rates over long periods. A direct experimental evaluation of the health risks from radon exposures at these low dose rates and exposure levels is currently impossible. Similarly, the biological effects of low radiation doses from radon are difficult to interpret, because most cells in the irradiated tissue receive no radiation exposure and it is not possible to distinguish between irradiated and unirradiated cells at low radiation doses. A new technology developed at the Pacific Northwest Laboratory uses an accelerator-based microbeam system to irradiate individual cells. This technology precisely controls the radiation dose rate to individual cells and the identification of each cell that was irradiated and provides a new means for determining the biological effects of extremely low doses of radiation, which is critical for understanding the role that radon, as well as other low-dose radiation, plays in the development of cancer.

Protecting Against Cancer-Therapy-Induced Cancer

One of the unfortunate long-term side effects of chemotherapy or radiation therapy for cancer is the induction of either secondary cancers or deleterious mutations. Scientists at Argonne National Laboratory are working on the development of chemicals for use as chemopreventive agents. A class of compounds known as aminothiols has been demonstrated to be effective in protecting mice against cancer and in reducing their risk for developing mutations, even when the compounds are taken up to 3 hours after exposure to ionizing radiation. Argonne is currently evaluating one aminothiol, Ethiothios, for its antimutagenic properties in chemotherapy patients.

Mechanism of DNA Double-Strand-Break Repair in Human Cells

A significant effect of exposure to ionizing radiation is that it can produce breaks in both strands of DNA. These breaks can subsequently delete genetic material from the affected cells following the cell's attempt to repair the damage. Radiation from exposure to radon is especially effective in producing these double-strand breaks. The repair of these breaks requires the activity of a large number of structural proteins and enzymes, only some of which have been identified and characterized.

Scientists at the Laboratory of Radiobiology and Environmental Health at the University of California, San Francisco, have characterized the role of one of the proteins involved in radiation-induced double-strand-break repair in DNA: the nuclear enzyme poly (ADP-ribose) polymerase. This enzyme binds tightly to both ends of a broken DNA molecule and participates in one of the initial steps involved in repairing the damage. Understanding the mechanisms that cells use to repair damaged DNA can help identify individuals with an increased sensitivity to radiation and lead to the development of strategies to reduce the effects of both natural and accidental radiation exposures.

Biotechnology Research Highlights

Molecular Analysis and Redesign of Enzymes

One strategy for the cleanup of toxic wastes at contaminated sites involves the identification and use of microor-

ganisms to detoxify harmful materials. Although this approach is theoretically appealing, the wide variety of toxicants found in different sites is not matched by a similarly complex inventory of microorganisms with the necessary spectrum of metabolic capabilities. Scientists at Pacific Northwest Laboratory are addressing this problem by genetically redesigning enzymes to modify their specificity or efficiency. They use information on the relationship between the structures and functions of potentially useful enzymes obtained from x-ray crystallography in computer analyses that simulate the interactions of an enzyme with its native and nonnative substrate. Specific mutations are then introduced into the genes for the enzymes of interest, and the function and specificity of the resultant protein product is characterized. Following its genetic redesign, the biodegradative enzyme P450cam was twice as efficient in its utilization of energy during the metabolism of its native substrate as was the unmodified enzyme (Figure 11–13). These results indicate that the creation of “designer enzymes” for use in bioremediation that can detoxify specific materials with a high efficiency is quite feasible and is a promising approach to addressing one of DOE’s most challenging missions.

Analogous studies are being conducted by scientists at Oak Ridge National Laboratory, who are investigating the CO₂ fixation enzyme RuBisCo (ribulose bis-phosphate carboxylase-oxygenase), a ubiquitous enzyme among photosynthetic organisms that is essential for the net conversion of atmospheric CO₂ into carbohydrates. This enzyme is a major cornerstone of living processes and serves a critical role in the production of biomass for energy and in the greenhouse effect. Using site-directed mutagenesis, the scientists have induced specific alterations at critical positions in the active site of this enzyme to see if they can alter its reactivity with CO₂ and oxygen. By making single-amino-acid changes in this enzyme, they have been able to dramatically increase RuBisCo’s utilization of CO₂ relative to oxygen. These studies are providing new insights into the mechanistic intricacies of this complex bifunctional enzyme that links the inorganic and organic pools of carbon on Earth (Figure 11–14).

Advanced Instrumentation for Structural Biology

Synchrotron beamlines supported by OHER’s structural biology program served hundreds of academic and industrial researchers during 1993. Both the Stanford Synchrotron Radiation Laboratory and the National Synchrotron Light Source at Brookhaven National Laboratory oper-

11–13. Biodegradative enzyme P450cam, one of the “designer enzymes” with potential use in bioremediation.

11–14. Enzyme RuBisCo, which links Earth’s organic and inorganic pools of carbon.

ated reliably for long periods. Pharmaceutical companies, such as Syntex, Abbott Laboratories, Upjohn, Glaxo, and Monsanto, increased their use of these resources. A noteworthy accomplishment from the academic community was the publication of detailed information about the structure of myosin, a protein that is the principal component of thick filaments in muscles. University of Wisconsin-Madison scientists used data obtained by crystallography at the Stanford synchrotron to refine the incomplete structures available to date, thereby providing a basis for developing a model of how myosin interacts with a second muscle protein, actin, to produce contraction of muscle tissue. The model should help medical scientists understand and treat muscle disorders.

Mapping and Sequencing of the Human Genome

A major thrust of the Department's Human Genome Program is to construct physical maps of all 24 types of human chromosomes and to develop the technologies and computational capabilities to develop and use these maps. These maps and associated technologies will provide the biomedical community with an unparalleled capacity to characterize genetic material, to assess the impacts of radiation and external agents, and to identify genetically based disorders before the appearance of symptoms.

Mapping of 2 of the 24 different human chromosomes is virtually complete with contiguous overlapping pieces of deoxyribonucleic acid (DNA) aligned from end to end, covering approximately two-thirds of the genetically active regions of each chromosome. This work is being performed at Human Genome Centers at Los Alamos and Lawrence Livermore National Laboratories, which are working on maps of chromosomes 16 and 19 respectively. Maps of five additional human chromosomes are being constructed by investigators at other national labs and universities supported by the Office of Health and Environmental Research. Another thrust of the Human Genome Program is the development and use of DNA sequencing technologies. DOE researchers have begun to determine the DNA sequence of several human chromosomes. One large-scale sequencing project, begun in 1991 at the California Institute of Technology and continuing at the University of Washington in Seattle, is concentrating on the human T-cell receptor complex, a region with important information for the development of molecules critical to a proper immune response. Other large-scale sequencing efforts are under way, including those of scientists at Brookhaven National Laboratory, who are developing approaches to significantly accelerate the rate at which DNA can be sequenced. Research by an international team of scientists has identified and sequenced the gene for adrenoleukodystrophy, a human genetic disease recently brought to public attention by the film *Lorenzo's Oil*. The disease affects 1 in every 20,000 males. The team relied on a gene identification strategy known as GRAIL (Gene Recognition and Analysis Internet Link) to isolate clones of the disease gene after experimental methods typically employed by gene hunters proved to be unsuccessful. GRAIL is an artificial-intelligence-based DNA sequence analysis program developed by scientists at Oak Ridge National Laboratory and is currently aiding investigators worldwide in the quest for genes that cause human genetic diseases.

Human Genome Distinguished Postdoctoral Research Fellowships

OHER began its Human Genome Distinguished Postdoctoral Fellowship Program in 1991 with four awards. Under the program, which is administered by the Oak Ridge Institute for Science and Education, 2-year fellowships are made to outstanding young scientists to carry out multidisciplinary research on topics related to the research activities of the DOE Human Genome Program. In 1992, six fellowships were awarded, and it is expected that five new awards (on average) will be awarded each year. The current fellows are working with research teams at Lawrence Berkeley and Los Alamos National Laboratories, five universities, and one private institution. Each fellow has a strong background in a research area, ranging from chemical engineering to biochemistry to computational biology to physics. This range of backgrounds is a natural fit to the highly interdisciplinary national Human Genome Project. The research areas of some of the current fellows include innovative DNA sequencing approaches, algorithm development for integrating physical and genetic maps, advanced flow-sorting techniques for chromosome purification, X-chromosome tagging studies, disease gene isolation, and the chemical synthesis of oligonucleotide arrays for DNA sequencing.

Abnormal Interactions Between Different Neurotransmitters

A methodology using positron emission tomography (PET) is being developed at DOE PET research centers to track the interactions in the brain between the neurotransmitters dopamine and serotonin. Because dopamine plays an important role in mood, motivation, motor activity, and psychotic symptomatology in schizophrenic patients, and because of serotonin's ability to regulate the release of brain dopamine, pharmaceutical companies have been targeting the interaction between these two neurotransmitters as a new approach to the design of antipsychotic drugs. Especially important are new drugs to treat patients who do not respond to conventional drug therapy. Using PET, scientists at DOE-funded laboratories are developing methods for directly examining the interaction between dopamine and serotonin and for probing the therapeutic efficacy of antipsychotic drugs. This research may affect the treatment of diseases classically defined as dopaminergic in origin (that is, Parkinson's disease, schizophrenia, and affective disorders) (Figure 11-15).

11–15. These PET images are made at Brookhaven National Laboratory using [^{11}C]raclopride, a tracer that binds to the dopamine D_2 receptor.

Environmental Research Highlights

Atmospheric Chemistry Program Summer Field Study

During August and September 1993, a multilaboratory team composed of DOE's Atmospheric Chemistry Program participants conducted a series of measurement flights over the North Atlantic Ocean to complete the second stage of the North Atlantic Regional Experiment (NARE). NARE is a component of the International Global Atmospheric Chemistry program, which is an international cooperative scientific effort addressing the chemical basis for global atmospheric change. The central goal of the DOE Atmospheric Chemistry Program's NARE measurements is to determine the influence of continental and marine pollutant sources on marine atmospheres, and thus develop an understanding of observed long-term trends in tropospheric ozone and general oxidizing capacity. Preliminary results show the importance of both surface and aircraft measurements in defining the vertical profile of chemical activity in the atmosphere. Surface measurements alone can miss the plume of pollutants over North America, which can be considerably above the Earth's surface.

Primary participants in NARE included Canada, the United Kingdom, and the United States. The DOE Atmospheric Chemistry Program contribution centered on the G-1 research aircraft (owned by Battelle, Pacific Northwest Laboratory), which was equipped to measure a vari-

ety of chemical species, including organics, peroxides, nitrogen and sulfur oxides, and aerosols. Data from these and the 1992 NARE flights are currently being analyzed to develop improved parameterizations for global chemical models and to evaluate transcontinental pollution input from non-U.S. sources. These measurements and their associated modeling efforts form an important resource for design and interpretation of transpacific pollutant transport—a primary Atmospheric Chemistry Program focus for 1994 and 1995.

Atmospheric Studies in Complex Terrain

The Atmospheric Studies in Complex Terrain (ASCOT) program conducted a field measurement campaign from August to October 1993 in the Front Range area of Colorado near DOE's Rocky Flats Plant. An array of remote sensors to measure vertical profiles of winds and temperatures was deployed over a line extending from near the Continental Divide to a location approximately 30 kilometers to the east of the mountains; a second array of remote wind sensors was deployed near a canyon mouth northwest of the Rocky Flats Plant. The data will be used to determine the influence of drainage winds issuing from the canyon on the local windfields at the plant and to understand how this influence is affected by ambient meteorological conditions. Such drainage winds are normally not represented in operational pollutant dispersion models that would be used in emergency response models.

Aerosols and Climate Forcing

During the past 2 years, the Office of Energy Research has coordinated an interagency, interuniversity team to assess the impact of anthropogenic aerosols on global climate forcing. In March 1993, this team published *Quantifying and Minimizing Uncertainty of Climate Forcing by Anthropogenic Aerosols* (DOE/NBB-0092T), a report that estimated the present global aerosol forcing effect and also detailed a scientific strategy for further evaluating this phenomenon. Extended versions of this report were published subsequently in *Science* and the *AMS Bulletin*.

The estimated global forcing by anthropogenic aerosols is of the order of -1 to -2 watts per square meter, a value comparable (but opposite in sign) to current estimates for anthropogenic greenhouse gases. The magnitude and significance of this effect had not been recognized until very recently. The current national and international global-change research programs need to include the importance of aerosols. DOE is currently working with other Federal agencies, the National Academy of Sciences, the

International Panel on Global Change, and the U.S. Global Change Research Program to increase the coordinated research on aerosol forcing and thus to reflect this growing recognition.

Atmospheric Ozone

In January, DOE published *Overview of the DOE Atmospheric Chemistry Program's Ozone Project* (DOE/ER-0575T), a report that reviewed the current understanding and uncertainties associated with stratospheric and free-tropospheric ozone as well as the related subject of ultraviolet-B radiation. This report noted that although substantial gains have been made in understanding ozone and ultraviolet-B trends, large gaps still exist. This is particularly true of ozone in the free troposphere and in the middle-latitude, lower stratosphere.

In reflection of this, DOE's Atmospheric Chemistry Program has launched a project addressing these issues. It was initiated by two invitations for research grant applications from the university community and a request for proposals from the DOE laboratories. The first round of university grants has been funded.

Ocean Margins Program

Very few measurements of the CO_2 in coastal oceans have ever been made. Therefore there is little understanding of the role of continental shelves in the exchange of CO_2 between the coastal shelf and the atmosphere above it, even though half of ocean photosynthesis is estimated to occur on continental shelves. Preliminary data from an exploratory cruise at Cape Hatteras, North Carolina, during May 1993 have demonstrated that the partial pressure of CO_2 over the whole water column had been reduced on the average by 55 percent, and up to 80 percent in the mixed layer. The magnitude of the exchange of CO_2 cannot be calculated from these data. However, the large gradient in CO_2 suggests that the continental shelf near Cape Hatteras could be a relatively large sink for atmospheric CO_2 during the spring.

Success of First Atmospheric Radiation Measurement Field Site

The first field site for the ARM Program began attracting attention soon after it began routine measurement operations. This site, in north-central Oklahoma and south-central Kansas, is managed by Argonne National Laboratory in collaboration with the University of Oklahoma and the National Oceanic and Atmospheric Administration. It fo-

cuses on understanding cloud and solar and infrared radiation interactions and will contribute substantially to the improvement of large-scale atmospheric models used for climate research and prediction. The data acquired at this site include surface meteorological and radiation data, vertical profiles of the atmospheric parameters important to the atmospheric radiation balance, periodic aircraft data for cloud and radiation measurements, and satellite data from other programs to document the top-of-the-atmosphere radiative fluxes.

The broad range of measurements at the site prompted offers for collaborative efforts. The site hosted North Carolina State University and the University Navstar Consortium (UNAVCO) to investigate the use of radio signals from the Global Positioning Satellite System for mapping water vapor distributions over the Cloud and Radiation Testbed (CART) site, a variable for which no adequate observation technique exists. Late in 1993, the program hosted researchers from the South Dakota School of Mines and Technology and the Jet Propulsion Laboratory to collaborate in a set of measurements, using the hyperspectral Airborne Visible and Infrared Imaging System (AVIRIS) on the NASA ER-2 aircraft. ARM site data will contribute to the accurate interpretation of the airborne imagery, and the imagery will contribute to the site surface characterization data base.

DOE is considering proposals for other collaborative efforts in succeeding years, and many others are anticipated, addressing not only atmospheric radiation and clouds but also surface hydrology and ecological questions where detailed and accurate measurement of the atmosphere and the air-surface interaction are required.

Advances in Instrumentation at the First Atmospheric Radiation Measurement Program Site in Oklahoma

Instrumentation intended for use by the ARM Program is pushing the state of the art in atmospheric remote sensing. In 1993, the newly developed Atmospheric Emitted Radiance Interferometer Spectrometer was successfully deployed for testing at the southern Great Plains ARM field site near Lamont, Oklahoma. This instrument, developed in the program's Instrument Development Program by the University of Wisconsin, is the first high-resolution interferometer spectrometer intended for routine and autonomous operational use at a field site. It measures the infrared spectrum from 520 to 3,020 per centimeter with a resolution of 0.48 per centimeter. The measurements will be used to validate models that predict this radiation, an important step in improving radiative com-

ponents of large-scale atmospheric models. Because this radiation is temperature- and constituent-dependent, these measurements will also be used to infer the profiles of key atmospheric properties and constituents, such as temperature and water vapor concentrations. Data from the spectrometer will be packaged with other site data for transmission to members of the ARM Science Team interested in remote sensing, radiation propagation modeling, and the assimilation of such profile data into atmospheric models. The Atmospheric Emitted Radiance Interferometer Spectrometer is the second instrument product to be introduced to routine site operations by the Instrument Development Program.

In 1992, the Multifilter Rotating Shadowband Radiometer, developed by investigators at the State University of New York at Albany, was deployed to the site for operational testing and integration into the operational instrument suite of the site. This radiometer represents one of the latest advances in surface-based radiometry. The Instrument Development Program is developing other state-of-the-art instruments, including cloud- and aerosol-sensing lidar instruments and cloud particle radar systems. Several of the systems will be operationally tested in the near future and may be procured for operational use within the next year.

Atmospheric Radiation Measurement Pilot Program in the Western Pacific

The ARM Program successfully completed the Pilot Radiometric Observation Experiment (PROBE), a 4-month collaborative pilot program (November 1992 through February 1993) in the tropical western Pacific Ocean with the Tropical Ocean-Global Atmosphere climate research program. The ARM pilot program provided valuable experience in operating a site in the Pacific Ocean and helped support Tropical Ocean-Global Atmosphere program objectives by measuring the radiometric properties of the atmosphere in the tropical western Pacific environment (atmospheric thermodynamic variables, sky cover, cloud base and aerosol concentrations, and atmospheric water vapor variability). The purpose of PROBE was to fully document, for the first time, the radiative energy balance of the tropical atmosphere, focusing specifically on the impact of tropical clouds on radiation at the surface. Combined with Tropical Ocean-Global Atmosphere program objectives to observe for an extended period the energy and moisture exchange between the ocean and the atmosphere, the PROBE and Tropical Ocean-Global Atmosphere data sets represent the first and only data sets appropriate to understanding the energy balance of the at-

mosphere in this area. These results will be used to guide the establishment of the scientific objectives for the ARM site to be established in 1994 and 1995 in the same area for a period of observations and experiments lasting up to 10 years.

Central Equatorial Pacific Experiment

In March and April 1993, the Scripps Institute of Oceanography, the National Oceanic and Atmospheric Administration, and the National Aeronautics and Space Administration conducted the Central Equatorial Pacific Experiment (CEPEX). DOE and the National Science Foundation funded this experiment to examine the validity of a thermostat effect believed to possibly limit greenhouse warming by producing cirrus (ice-particle clouds) anvils that spread out over millions of square kilometers. These cirrus anvils are theorized to trap the outgoing infrared radiation and reduce the incoming solar radiation by as much as one-half. The net result is that though the clouds owe their existence to high sea-surface temperatures, they also simultaneously limit the increase of sea-surface temperatures, thus acting as a thermostat.

This field program was highly successful in acquiring data needed to evaluate the thermostat hypothesis. The project was staged from the Fiji Islands, using four research aircraft, including a Lockheed Electra from the National Center for Atmospheric Research, a Lockheed P-3 from the National Oceanic and Atmospheric Administration, an ER-2 from the National Aeronautics and Space Administration, and an Aeromet Corporation Lear Jet. Aircraft measurements were taken between 100 and 70,000 feet (30 and 20,000 meters), in addition to ship, island, and buoy measurements at the surface, including the ARM Program site supporting the Tropical Ocean-Global Atmosphere program. The initial assessments of the data acquired indicate near-ideal conditions were encountered and that detailed analysis will produce illuminating and important results.

Autonomous Expendable Conductivity Temperature Depth Instrument

On May 11, 1993, a U.S. patent was granted on the Autonomous Expendable Conductivity Temperature Depth Instrument. The patent was granted to John Downing of Battelle Memorial Institute; Kim McCoy of Ocean Sensors, Inc., San Diego, California; and Michael Riches of the DOE's Environmental Sciences Division. They are negotiating an agreement to license the technology to a U.S. firm for commercialization.

The Autonomous Expendable Conductivity Temperature Depth Instrument is an expendable oceanographic probe that collects data from remote ocean locations and subsequently transmits it to satellites—faster and less expensive than current methods allow. Two additional patents are being explored.

Russian Climate Data Reports

The Carbon Dioxide Information Analysis Center (CDIAC), in collaboration with the All-Russian Research Institute of Hydrometeorological Information-World Data Center (RIHMI-WDC) (Obninsk, Russia), has compiled the citations for the second of four dual-language volumes in its Selected Translated Abstracts of Russian-Language Climate-Change Publications series (see Bibliography). The first volume covers the Earth's surface energy budget, the second covers clouds, and the third and fourth volumes are planned to cover aerosols and general circulation models, respectively (see Bibliography). The first two volumes in the series were compiled by CDIAC based on abstracts translated into English by RIHMI-WDC. The series opens up to Western researchers a wealth of climate change literature that has previously been available only in Russian.

Complex Chemical Mixtures at DOE Sites

As part of basic research to investigate molecular-scale mechanisms that control interactions among organically complexed radionuclides and mineral surfaces, contaminant mixtures on DOE lands were inventoried and published in a DOE report, *Chemical Contaminants on DOE Lands and Selection of Contaminant Mixtures for Subsurface Research*. The inventory was designed to identify generic, representative experimental chemical mixtures for basic research on subsurface geochemical and microbiological processes. Frequencies of association were statistically analyzed, and early data on the presence of mixed contaminants on DOE lands were assembled. The report was requested by and widely distributed to DOE sites and the remediation industry; more than 2,000 copies were distributed, and the report is in a second printing.

Natural Microbial Heterogeneity in the Subsurface Biosphere

Observations of microbiota in sediments at the Hanford site suggest that these populations, although low in total

biomass and widely distributed, can be stimulated. This is noteworthy, because active in-situ populations can be useful for cleanup. At the Subsurface Experimental Research Facility (SERF) at Pacific Northwest Laboratory, the natural distribution of microorganisms in laboratory experiments was reproduced using special laboratory devices called two-dimensional flow cells that are designed to simulate an underground aquifer. One goal of the study was to determine if layered strata represent distinct microbial ecosystems. These experiments confirmed the importance of natural heterogeneities, such as the contact between saturated and unsaturated geological units, and identified microsites that may be important in supporting microbial populations. Knowing that microbial biodegradation occurs preferentially at the boundaries between subsurface strata is important in the design of effective in-situ bioremediation technologies: These technologies must target dispersed or selectively concentrated populations more carefully, by nutrient or other amendments.

Anaerobic Thermophiles in Rocks at Depths of 3,000 Meters

Evidence of the presence of anaerobic thermophilic bacteria in rocks of a deep basin is stronger now that an OHER scientific team, using mutually supporting biochemical and geochemical tracers and a variety of other interpretative methods, has begun to document this presence at a site in rural Virginia. This discovery of possibly new thermophiles may be of commercial value in waste cleanup and the chemical industry.

Information on the presence of such microbiota also has possible implications for the petroleum industry because these microbiota are determinants of whether buried basins are "closed," and hence likely to preserve oil and natural gas resources, or "open." Ten different lines of evidence were developed that showed that the organisms were not artifacts of drilling (that is, they were not derived from drilling fluids). Drilling and sampling protocols pioneered by DOE for deep microbiology research also showed that samples at a Texaco Oil Company site were not contaminated. When studied by a cluster analysis method, bacteria from surface soils, drilling muds, and drilling waters proved to be distinct from deep bacterial assemblages (the presence of similar assemblages throughout the site would have been evidence that the microbiota were derived from drilling fluids). DOE's deep microbiology sampling and analysis methods are being transferred by OHER to DOE sites by a series of workshops to train drilling and operations staff in these advanced techniques

and in how they can be applied to bioremediation. DOE is releasing these newly discovered thermophiles and other cultures from its Subsurface Microbiology Culture Collection housed at Florida State University.

Semtner-Chervin Ocean Modeling

Albert Semtner of the Naval Postgraduate School and Robert Chervin of the National Center for Atmospheric Research were honored at the Computerworld Smithsonian Awards dinner on June 7, 1993, where they received the 1993 award for Breakthrough Computational Science. Their seminal work in ocean modeling for climate applications has been partly supported by the Computer Hardware, Advanced Mathematics and Model Physics Program. The award is given annually for the best use of computational science to "significantly increase the possibilities for improvement in the human condition; solve or make notable progress on a previously intractable problem; set new, replicable standards for scientific endeavor; and create new technological tools with which to effect change." Their accomplishments also were highlighted recently in a *Science* magazine article (vol. 260 (April 2, 1993), p. 32); a sidebar to the article on the development of the parallel version of the code contains a paragraph on the Los Alamos National Laboratory CM-5 supercomputer implementation.

Atmospheric Model Intercomparison

DOE is providing major support for the international Atmospheric Model Intercomparison Project. This study, jointly sponsored by the Department (with Lawrence Livermore leading the DOE effort) and the World Meteorological Organization's World Climate Program, involves standardized atmospheric data sets for the years 1978-88, which the models will attempt to emulate. More than two-thirds of 30 participating modeling groups worldwide have completed initial model simulations for the period 1979 to 1988. The resulting simulations will be used to diagnose problems with the models and identify possible solutions and improvements. This represents a major step toward resolving uncertainties in the models, because different models have produced different estimates of climatic change. Related diagnostic and model intercomparison projects are investigating the causes of these model disagreements, especially the role of cloud-radiation interactions and other feedbacks. Chief among these are an overall cold bias in the upper troposphere in higher latitudes, generally excessive precipitation in the

middle and high latitudes, and excessively strong midlatitude zonal westerlies. Some of these errors and disagreements are known to be sensitive to the treatment of surface interactions, convection and mixing processes; ongoing analyses by the Program for Climate Model Diagnosis and Intercomparison and by the Atmospheric Model Intercomparison Project are expected to clarify the nature and model-dependence of these and other disagreements.

Carbon Dioxide Survey

The Global Survey of CO₂ in the Oceans has nearly completed its work in both the Atlantic and the Pacific Oceans. The survey was undertaken by DOE national laboratories and leading U.S. universities in conjunction with cruises of the World Ocean Circulation Experiment. The goal of the survey is to obtain a high-accuracy "snapshot" of the distribution of carbon dioxide (CO₂) within the world's oceans. Over the past 3 years, survey participants have covered approximately 40,000 nautical miles of cruise track in the Pacific Ocean and 10,000 nautical miles in the Atlantic Ocean. This has involved more than 600 days at sea aboard U.S. and foreign research vessels, during which the team analyzed more than 18,000 individual water samples for CO₂ parameters. An extensive data quality control program established at the start of the survey, including the provision of certified reference materials and certified analytical equipment, has already produced a data set of unprecedented accuracy and magnitude.

Researchers will use the data set as input for models of the global carbon cycle. In addition, team members are using the survey data to estimate large-scale fluxes of CO₂ that are driven by water circulation within the ocean basins as well as by the exchange between the ocean and the atmosphere. Such studies, together with models of the atmospheric transport of CO₂, will allow the locations and magnitudes of net sources or sinks of CO₂ to be inferred on a planetary scale. The data set will also improve estimates of the uptake of fossil-fuel CO₂ by the oceans, both through modeling and by correlating fossil-fuel CO₂ distribution with the distribution of other anthropogenic compounds within the oceans. Uptake by the oceans is the largest single factor affecting the prediction of future greenhouse gas levels for any given CO₂-release scenario.

The measurement teams are now preparing for the final stages of the survey, which involves a 14-month study of the Indian Ocean starting in 1995. In addition, the task of management, quality checking, and distribution of the survey data is now well under way.

FUSION ENERGY

Introduction

Fusion is the process by which the Sun and other stars produce energy. It is the power that lights the universe. Fusion occurs when the nuclei of lighter elements, such as hydrogen, are joined together at extremely high temperatures and pressures to form heavier elements, such as helium. For more than 40 years, scientists around the world have worked to control fusion reactions and make this potentially vast energy resource available for use on Earth. This is a very difficult technical task, but steady progress has been made.

Fusion has many potential advantages as an energy source. Fusion fuels are essentially inexhaustible. Inexpensive and easily obtainable elements such as deuterium fuel (a heavy isotope of hydrogen that can be readily obtained from seawater) and lithium (for breeding tritium fuel, a radioactive isotope of hydrogen) could provide sufficient energy for many thousands of years at current levels of world power consumption.

Equally important is fusion's potential to provide energy with minimal impact on the environment. Fusion produces no combustion products such as CO_2 and other greenhouse gases. The ultimate "ash" of the fusion reaction, helium, is a benign material. Thus, widespread use of fusion could yield a great amount of power without the concerns for the impact on the environment of phenomena such as acid rain, smog, and the greenhouse effect, which are often associated with the burning of fossil fuels. Fusion reactors would contain only small quantities of fuel at any time, thus eliminating the potential for a runaway reaction and greatly reducing the potential for damage to the powerplant when cooling requirements are not met.

Because a commercial fusion power reactor would generate high energy neutrons, powerplants would need shielding to protect workers and mechanisms to handle the radioactivity induced within the reactor structure (mainly in the form of activated structural materials, which are immobile solids). Although such a reactor might generate a volume of radioactive waste roughly comparable to that of an equivalent fission reactor, the fusion waste would be less highly radioactive and thus considered less hazardous than fission waste. The radioactive-waste hazards from fusion reactors, based on the most meaningful indices combining volume, radiotoxicity, and longevity, can be expected to be at least 100 times smaller than those

from fission-based light-water reactors (current nuclear powerplants use fission reactors to create power). In addition, the development of low-activation materials or advanced fuel cycles would give fusion reactors the potential to produce energy with little or no high-level radioactive waste, thus minimizing the disposal problems relative to those faced by fission reactors.

Fusion energy systems will be less likely than fission energy systems to contribute to the acquisition of nuclear weapons capability by subnational groups, and it will be easier to safeguard fusion systems against clandestine production and use of fissile materials by governments.

The greatest impact of successfully commercialized fusion energy, which could occur by the middle of the next century, probably would be seen in the electricity industry, as fusion powerplants become competitive with nuclear fission and fossil fuels. Environmental and safety benefits would be realized through reduced use of nuclear fission and fossil fuels; and the decreased demand for burning coal and petroleum for electricity generation would preserve those resources for conversion into other materials (for example, polymers). In addition, fusion powerplant designs could incorporate materials for producing medical isotopes, or could use excess heat for other industrial procedures. However, controlled fusion has yet to produce more power than is consumed in producing the fusion reactions, and the economics of electric power produced from fusion energy are not now well known. The best calculations that can be made indicate that the cost of fusion-produced electricity is bracketed on the low side by the cost of electricity produced by the best experience and on the high side by the median experience of light-water fission reactors.

Achieving the benefits of controlled fusion reactions is a difficult, long-term technical challenge. The basic task is to confine an electrically conducting gas, termed a plasma, at the high temperatures and pressures required for fusion reactions to occur. Nuclei, which are electrically charged, repel each other; therefore, high nuclei velocity, corresponding to a temperature in excess of 100 million degrees Celsius (the temperature of the Sun) is required to force them close enough to one another for a fusion reaction.

In principle, a number of different nuclear reactions could be used in a fusion energy-generating system. The fusion reaction that is easiest to attain involves two isotopes of hydrogen, deuterium and tritium. Deuterium is abundant in water and is easily recovered. Tritium is not found in large amounts in nature, but it can be produced from lithium, which is widely available.

Approaches to Controlled Fusion

In the fusion reactions of the Sun and other stars, the plasma is confined by gravitational forces. On Earth, the plasma must be confined, and the fusion reaction sustained, through other means. Two approaches to achieving net energy production through controlled fusion reactions are being considered: magnetic confinement and inertial confinement.

In magnetic confinement fusion reactions, the plasma is confined by an intense magnetic field and heated by external sources to achieve a self-sustaining fusion reaction. A continuous source of energy can be maintained as small amounts of fresh fuel are injected. In inertial confinement fusion reactions, small fuel pellets are bombarded by high-intensity laser or particle beams to produce a very small quantity of high-density plasma, which is confined for a very short time by its own inertia. This produces short, sequential "pulses" of high-intensity energy.

Most of the U.S. and world effort in fusion energy research and development (R&D) is focused on magnetic confinement, which has been under development since the early 1950s as a potential long-range energy option. DOE's Office of Energy Research manages the U.S. program in this area. The Office of Defense Programs manages inertial confinement fusion research, which has been under development since the early 1970s. The near-term applications of inertial confinement fusion are military, but many people familiar with the program envision the possibility of civilian energy production applications. The Office of Energy Research is supporting the program by working to develop the heavy-ion accelerators that could be a major part of an inertial fusion energy system.

Fusion Energy Policy

The Energy Policy Act of 1992 directs the Department to conduct a fusion energy program that by the year 2010 will produce a technology demonstration that will verify the practicability of commercial electric power production from fusion. The Act specifies that the program must

1. Be broad-based
2. Participate in the International Thermonuclear Experimental Reactor
3. Develop technology with industrial participation
4. Design and construct a major new fusion research machine

5. Conduct research and development on inertial fusion energy

Magnetic Fusion Energy

Introduction

The Department's long-term goals for fusion energy include supporting the program as laid out in the Energy Policy Act of 1992, operating a demonstration powerplant by 2025, and operating a commercial powerplant by 2040. In supporting research aimed at achieving these long-term goals, DOE is actively cooperating with the magnetic fusion energy programs of other countries. The International Thermonuclear Experimental Reactor (ITER) Program, which involves close intergovernmental collaboration among the fusion programs of the United States, the European Community, Japan, and the Russian Federation, is an outstanding example of this international cooperation. The 3-year ITER conceptual design effort was successfully completed in December 1990, and the four parties signed an agreement on July 21, 1992, to conduct a 6-year effort of engineering design activities for ITER (Figure 11-16). The benefits of this approach are twofold: the science and technology base is expanded without duplication of effort, and the costs of the fusion program's most expensive research facility are shared. (see "International Cooperation" below).

11-16. Former Secretary Watkins (right), along with Russian Minister Mikhailov (left), Japanese Minister Hirabayashi, and European Community Ambassador Van Agt sign the ITER EDA Agreement in Washington, DC, on July 21, 1992.

Status of Program and Remaining Questions

In spite of the immense technical challenge of the magnetic fusion goal, the world's fusion programs have made significant progress, and the scientific feasibility of fusion looks promising. More than three decades of international effort has yielded an increasingly solid scientific basis for understanding the behavior of magnetically confined plasma. This understanding has led to a worldwide consensus that the most effective way to magnetically confine a fusion plasma is in a toroidal, or doughnut-shaped, device.

The leading toroidal confinement concept is the tokamak. The world's leading tokamak facilities, the Tokamak Fusion Test Reactor (TFTR) at the Princeton Plasma

Physics Laboratory (Figure 11-17); the Joint European Torus, the European Community's principal fusion research facility, located at Culham, England; and the JT-60 Upgrade, located at Naka, Japan, have achieved plasma conditions within a factor of 10 of those required to produce net power. Until recently, energy had not been produced in these experiments in any significant amount because only the less reactive 100 percent deuterium fuel had been used. However, an experiment at the Joint European Torus tokamak in October 1991 used a limited amount (13 percent) of tritium in combination with deuterium. This experiment produced a peak fusion power of nearly 2 million watts—equivalent to the power produced by the engine of a small executive jet.

A series of experiments using an optimum fifty-fifty mixture of deuterium and tritium was conducted in TFTR

11-17. Tokamak Fusion Test Reactor at the Princeton Plasma Physics Laboratory in New Jersey.

beginning in December 1993. These experiments are designed to provide important information on the physics of deuterium-tritium plasmas and to demonstrate the production of about 10 million watts of fusion power, both of which are important for the International Thermonuclear Experimental Reactor.

Although the Fusion program has made substantial progress, major physics issues remain. For example, how is the energy lost from a tokamak plasma? This energy loss increases the heat input necessary to sustain the high temperatures required for fusion. In 1989, the U.S. fusion program began a major effort to understand this problem, using new diagnostic and computer modeling tools developed by U.S. researchers to identify the phenomena responsible for increasing the transport of energy out of the tokamak. These tools are providing new insights into the plasma physics processes that control energy transport. Methods for transport reduction have been confirmed, and research is continuing. Qualitative agreement between measured turbulence in the interior of the plasma and numerical simulations has been achieved. Other important unanswered scientific questions include the following:

1. *Burning plasma physics:* How does the plasma behave once fusion reactions are producing sufficient heat for a self-sustaining reaction?
2. *Magnetic confinement concept optimization:* How can confinement best be achieved—with what specific magnetic configuration, heating and fueling techniques, and power and particle-exhaust methods?
3. *Materials:* What materials are best suited to use in a reactor to provide high margins of safety and low levels of induced radioactivity?
4. *Nuclear technology:* How can fusion energy be efficiently and safely converted into electricity?

The work of DOE's Magnetic Fusion Energy Program on these issues also forms the basis for U.S. participation in international fusion activities and provides the focus for planning for future international research facilities.

Burning Plasma

A major technical goal of the Magnetic Fusion Energy Program is to achieve and study a burning fusion plasma—that is, a plasma whose temperature is primarily sustained by fusion reactions with minimal external energy input. The condition where the power produced by the fusion reaction in the plasma is equal to the power required to heat the plasma is termed scientific breakeven. In 1993,

the program made good progress toward a major milestone—approximate fusion energy breakeven in the Tokamak Fusion Test Reactor (TFTR). Final installation of all the hardware needed to operate with tritium was completed. In addition, integrated systems tests of all the hardware were carried out with small quantities of tritium.

Magnetic Confinement

The second main area of technical work in the Magnetic Fusion Energy Program is determining the most effective and economical way to achieve magnetic confinement. This includes both improving the tokamak concept and developing alternative concepts. Research on this key issue is being coordinated internationally to maintain the broadest scientific coverage at minimum cost. Much of the past effort in this area has been focused on improving the efficiency of magnetic fields, measured by a parameter called "beta." Increasing beta would reduce the magnetic field required for a fusion reactor. This is especially important because the magnets are one of the most costly parts of a reactor. Progress toward increasing beta has been good enough to allow more of the current effort to shift toward increasing plasma confinement time and stability, understanding heat- and particle-transport processes in plasmas, and improving the techniques used to drive the internal electrical currents needed to confine and stabilize the plasma.

Scientists believe that plasma stability at high temperatures can be achieved with lower plasma current if a condition called "second stability" can be achieved. The lower current would be less disruptive and thus safer and also could lead to more economical tokamak designs. Theoretical calculations indicate that the shape of the plasma within the doughnut-shaped tokamak can be tailored to allow access to the second-stability regime. Another requirement for the "second-stability regime" is detailed control of the plasma parameter profiles, which can be achieved by using RF waves. To test these theories, the Princeton Beta Experiment Modified was upgraded in 1988. Encouraging improvements in stability limits were observed during operations in 1989. However, this facility was mothballed during 1990 and 1991 because of budgetary constraints. Profile-control and stability experiments were resumed in 1992 and ended in November 1993. The facility was once again mothballed because of budget constraints.

The principal U.S. tokamak facility investigating the above issues is the Doublet III-D facility at General Atomics in La Jolla, California (Figure 11-18), which is equipped with a diverter. A diverter is the part of the tokamak that handles the bulk of power and particle exhaust of the de-

11-18. Interior view of Doublet III-D fusion device's vacuum vessel.

vice. DIII-D's construction was jointly funded by Japan; and the DIII-D program has a strong collaboration with Europe, Japan, and many U.S. national laboratories. The DIII-D facility has achieved record beta levels (about 12 percent), well in excess of the range needed for an economical reactor; and it has produced higher levels of confinement factor than previously predicted or demonstrated. Additionally, it has demonstrated current drive with RF waves as needed under reactor conditions and has incorporated an advanced cryo-pump as part of the diverter, which is effective in controlling plasma density independently of plasma current (a first for a tokamak).

At the Massachusetts Institute of Technology, the state-of-the-art Alcator C-MOD tokamak, which began operation in April 1993, continues to explore high-density, high-field tokamaks. This device will extend previous experiments on shaped plasmas that have magnetic diverters, and will be heated using RF waves. It will also be used for studies on energy confinement, control of fuel and impurities in the plasma, and the handling of the heat coming out of the plasma.

The Advanced Toroidal Facility at Oak Ridge National Laboratory has carried out investigations of the stellarator concept, a tokamak-related toroidal configuration that provides an alternate path to a disruption-free, steady-state fusion reactor concept. The Advanced Toroidal Facility has also contributed to the understanding of tokamak physics. However, due to budget limitations, the Advanced Toroidal Facility was mothballed in 1992 and 1993. Some small-scale, exploratory experiments and contact with foreign programs will be continued to support the development of the stellarator concept.

The future focus of the U.S. Magnetic Confinement research program will be on the Tokamak Physics Experiment (TPX), which is entering the engineering design phase. The conceptual design of TPX was completed, reviewed, and endorsed by an international committee of fusion and project management experts in April 1993. The goal of TPX is to develop the physics basis for an economically attractive fusion demonstration powerplant and to develop the technology and advanced control techniques required for continuous operation of such a plant. Specifically, it will explore techniques for operating tokamaks in regimes with both good confinement and efficient use of the magnetic field that confines the plasma. It will also develop the technologies required for continuous operation of major systems, such as the magnets, heating systems, and the diverters, that must withstand the heat coming out of the plasma. TPX may also develop improved operating modes for the second phase of the ITER Program. U.S. industry will be involved in both the design and fabrication of all major TPX subsystems. Such involvement will help U.S. industry be competitive in the bidding for design and fabrication of ITER components and systems.

Fusion Systems Studies

The Magnetic Fusion Energy Program has completed the Advanced Reactor Innovations Evaluation Study (ARIES), which investigated the potential economics, safety, and environmental benefits of various options for fusion powerplants based on the tokamak. The participants considered a range of possibly attractive tokamak powerplant designs with various degrees of extrapolation from today's physics and technology bases. The study considered several fusion powerplant designs. Results indicate that economically competitive fusion powerplants can be designed and built even with only modest improvements in plasma performance over what is possible today. The major advantages of these fusion powerplants would be in increased safety and environmental acceptability.

Materials

A fusion powerplant must be constructed from materials that can withstand the heat and neutrons from a burning plasma. To accommodate concerns related to safety and waste management, the plant also must be designed to ensure that radioactivity is well contained and short-lived. Research aimed at identifying and testing materials for fusion systems is being pursued through international cooperative agreements that provide significant foreign contributions for operations at U.S. research facilities. For

example, the United States, the European Community, Japan, and Canada have collaborated to fund and conduct experiments at DOE's Fast Flux Test Facility at Hanford, Washington, and at the Experimental Breeder Reactor-II (EBR-II) at the Idaho National Engineering Laboratory. A wide range of structural materials and several different tritium-breeding materials that will produce tritium fuel from nuclear reactions in lithium have been tested.

The Low-Activation Materials Program has achieved significant progress in developing structural materials that promise satisfactory economics. Collaborative work at Oak Ridge National Laboratory and Pacific Northwest Laboratory found that changing the composition of certain high-strength steels (for example, substituting tungsten for molybdenum) produced superior performance and decreased radioactivity. In some cases, radioactivity levels predicted to last for centuries after decommissioning were reduced a thousandfold, which would allow simplified waste disposal after a storage time of less than 100 years. Advanced materials based on vanadium and silicon carbide are also being studied.

Nuclear Technology

DOE is involved in research on the nuclear technology needed to convert fusion energy into electricity and to produce tritium for fuel. Because tritium does not occur in abundance in nature, fusion powerplants that use tritium will have to produce this element from lithium, which could be introduced in a solid or liquid form. In the liquid form, lithium could also be used as a coolant.

A difficulty with the use of lithium as a coolant is that magnetic fields retard the motion of such a liquid metal. A joint U.S.-German project at Argonne National Laboratory has successfully tested a solution to this problem by changing the shape of the conduits that the metal flows through. An ongoing U.S.-Russian project is studying other approaches in tests conducted at Argonne National Laboratory.

Using lithium in a solid-material matrix to breed tritium also is being investigated. The United States, Japan, and Canada have completed an experiment in the Fast Flux Test Facility's Materials Open Test Assembly to study the tritium-release characteristics of the solid materials in a simulated fusion neutron environment. Preliminary results from examinations of these materials indicate that the materials are stable and release tritium easily.

After tritium is derived from lithium, the tritium must be safely handled and processed for use in the fusion reactor (Figure 11-19). To help develop and demonstrate the technology necessary to accomplish this task, the United

11-19. Extensive storage and delivery system for safe handling and processing of tritium.

States built the Tritium Systems Test Assembly at Los Alamos National Laboratory. This prototype fusion-fuel processing system has already demonstrated the technology to process up to 1 kilogram of tritium per day, and completed a month-long continuous operation test in 1992. The tritium-processing capacity of this system is a significant portion of that required for a fusion power reactor.

International Cooperation

The President's budget message, "A Vision of Change for America," called the International Thermonuclear Experimental Reactor (ITER) the centerpiece of the U.S. fusion program. ITER is the essential step between the exploration of the physics of fusion and the engineering and technology development necessary to bring fusion powerplants to the energy market.

In 1990, the United States, the Soviet Union, Japan, and the European Community completed the conceptual design phase of the ITER Program. The major objective of such a future facility would be to demonstrate the scientific and technological feasibility of fusion power. The ITER joint work evolved from proposals made by Soviet General Secretary Gorbachev and President Reagan at the 1985 Geneva summit. Work included both the conceptual design itself and validating R&D.

In July 1992, the United States, the Russian Federation, Japan, and the European Community signed an agreement to conduct a 6-year effort of engineering design activities for ITER. Then-Secretary Watkins signed the agreement for the United States. The major objective of such a future facility would be to demonstrate the scien-

tific and technological feasibility of fusion power. The tasks to be performed during engineering design activities of the ITER activity include detailed design of the device and the necessary supporting R&D. The completion of engineering design activities in July 1998 will provide the technical basis for decisions by the four ITER parties on whether to construct ITER, whether and how to collaborate in such a construction, and at which site it should be constructed.

During 1992, researchers continued work in their home laboratories in support of ITER. With the start of the engineering design activities, the ITER Joint Central Team, responsible for conducting design efforts, is located at three co-centers: San Diego, California; Naka, Japan; and Garching, Germany. The ITER Director and the project integration staff are located in San Diego. Funding for the San Diego co-center is provided by DOE and the State of California.

The Director's first tasks have been staffing the Joint Central Team with equal numbers of personnel from each party, developing the preliminary engineering design of ITER, and formulating a proposed work program that specifies the R&D tasks to be performed by each party's home team. The supervisory ITER Council has approved the basic design parameters for ITER following the parties' study of detailed technical objectives and a technical review of the Director's design proposal.

The United States also continued cooperative programs, both through bilateral fusion energy agreements with all parties having significant fusion programs, including Japan, the Russian Federation, the European Community, and Canada, and through multilateral arrangements under the auspices of the international energy agencies of both the Organization for Economic Cooperation and Development and the United Nations. International collaboration is now a major element of the U.S. fusion program strategy, and the United States has successfully increased coordination of complementary activities. Collaboration with the European Community focuses on the areas of impurity control in tokamaks and long-pulse tokamak operation, where the Europeans have prepared major facilities. Collaboration with Japan is comprehensive and includes continuing joint efforts in fusion-fuel processing and superconducting magnet technology using test facilities in both countries. Collaborative activities with Russia are also comprehensive, encompassing both science and technology, and concentrating on materials and overall development. Furthermore, many subcontracts have been put in place under which highly qualified technical personnel at Russian institutions are contributing to priority U.S. fusion physics and technology missions. Addition-

ally, a formal agreement on the environmental aspects of fusion nuclear energy technology has been signed, and an agreement is about to be signed on fusion's safety aspects (including development of low-activation materials). Collaborative work in the environment and safety area is now under way.

Inertial Fusion Energy

In inertial confinement fusion experiments, a laser or particle beam is used to deliver energy to the outer surface of a pellet that contains a mixture of deuterium and tritium fuel. The outer surface ablates, compressing and igniting the fuel at the center of the pellet. The inertia of the mass of the pellet confines the explosion until a significant portion of the fuel has fused—hence the term “inertial fusion.”

Inertial fusion energy program efforts are based on the assumption that ignition and high-gain burn of a deuterium-tritium pellet can be demonstrated in the laboratory. This work is being carried out within DOE's defense programs.

Based on defense program experiments on the Nova facility, the Fusion Policy Advisory Committee and the Secretary of Energy are confident that a neodymium-glass laser facility with about 2 megajoules of energy would be capable of demonstrating ignition in the laboratory and could be operational around the year 2000. Such a laser system is planned for a new facility, the National Ignition Facility (Figure 11-20).

For energy applications, in addition to the blankets and materials needed for all deuterium-tritium fusion approaches, the following critical problems that pertain to inertial fusion energy must be successfully addressed:

1. Development of efficient, high-power drivers that can be operated at useful repetition rates of several times per second
2. Design of pellets that can be inexpensively produced, efficiently driven, and stably imploded, and that yield high gain
3. Design of experimental chambers that contain the microexplosion products and adequately protect the driver

To understand the technology issues surrounding a 1,000-megawatt inertial-fusion powerplant, two industry-led studies were completed in 1993. Each energy design team considered cases that involved a krypton-fluoride

11-20. Nova, the world's most powerful laser, is used for both defense and energy research.

laser driver and a heavy-ion driver. The studies identified many of the R&D activities that would be needed to develop inertial fusion energy. Final reports from these studies have been distributed.

Reports prepared by the Fusion Policy Advisory Committee and the National Academy of Sciences indicate that a heavy-ion beam is the driver of choice to meet energy requirements. Research conducted by the Heavy Ion Fusion Accelerator Research Program between 1982 and 1991 provided the conceptual basis for a heavy-ion driver. Multiple beams of heavy ions were accelerated and amplified in a low-energy induction linac system, demonstrating the basic feasibility of a driver concept with potentially acceptable cost and beam quality. By employing low-mass ions, the next step, called the Induction Linac Systems Experiment (ILSE), can achieve high-speed ions and realistically test concepts of beam merging, drift compression, and focusing within the stringent beam-quality (spot-size) requirements imposed by the need to focus energy on a small inertial fusion target. A recent report of the Fusion Energy Advisory Committee fully agrees with the earlier reports and supports the ILSE project as having high technical merit.

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CHAPTER 12

SCIENCE EDUCATION AND TECHNICAL INFORMATION

INTRODUCTION

To strengthen DOE's commitment to the Nation's competitiveness, in 1993 the Secretary realigned the Department's outreach effort by combining science and education activities with scientific and technical information activities to provide more emphasis in these key areas.

SCIENCE, MATHEMATICS, AND ENGINEERING EDUCATION

Introduction

The Department of Energy has supported basic and applied research through fellowships and research appointments since its creation in 1977. This mandate originates in the Energy Reorganization Act of 1974 (Public Law 93-438), as amended, and the Department of Energy Organization Act (Public Law 95-91), which authorize support for education and training activities necessary to ensure the Nation has an adequate technical workforce in energy-related research and development fields. A 1981 policy limited this support to the post-secondary level, but the Department of Energy Science Education Enhancement Act (Public Law 101-510, sections 3161-3168) expands the authorization to include all education levels from precollege through postdoctoral and amends the Depart-

ment of Energy Organization Act to make support for science education a major mission of the Department. In 1990, the Office of University and Science Education Programs was created within the Office of Energy Research to oversee all the Department's education activities.

The goal of the Department's education action plan is to support precollege student and teacher activities, undergraduate and graduate programs, and use of its facilities, partnerships, and coordination assistance (Figures 12-1, 12-2, and 12-3). Its science education mission is based on the following premises:

1. Serious efforts to produce students with excellent math and science skills must begin at the elementary school level and reach all students
2. Science and math teachers must become full partners in the scientific community
3. The Department's science education programs must encourage full participation by women and minorities
4. The Department should fully use the unique resources of its national laboratories and research facilities to improve math and science education
5. Departmental efforts must be fully integrated and compatible with those sponsored by other Federal agencies and state initiatives to reform and improve science education

The Department provides its most substantial support to mathematics and science education through its 10 national laboratories and 29 additional, specialized research facilities. Each of these scientific and technical centers plans and administers a range of precollege

12-1. DOE's education programs allow undergraduate and graduate students to conduct scientific research at many of its national laboratories and facilities.

and university science education programs, which vary according to equipment available, laboratory specializations, and local needs. Students and teachers gain hands-on experience with the Department's unique cutting-edge science and technology tools, such as the Fermi Accelerator, lasers, electron microscopes, advanced robotics, and supercomputers. This collection of scientific and technical resources kindles excitement for science in students and promotes science literacy for the general public.

The Department's \$136.53 million in appropriated funds for science and mathematics education programs in 1994 is approximately 7 percent more than 1993's when adjusted for comparability, and reflects the commitment in its budget request to science and mathematics education. In addition, the approximately \$600 million in university research grants that will be provided in 1994 will indirectly support the training of more than 5,500 graduate students involved in the research.

The Office of Energy Research and the Science and Technology Advisor, originally responsible for overseeing the multidisciplinary national laboratories, received during 1992-1993 the highest level of the Department's education funding and the largest increase in precollege funding. This education funding responsibility now rests with the Office of Science Education and Technical Information. For 1994, education programs for this organization will total \$58 million. The Office of Environmental Management, which focuses primarily on the undergraduate level, will rank second in funding for education

12-2. The Frank Lloyd Wright-inspired Leon M. Lederman Science Education Center at Fermilab celebrated its first anniversary. During the year, approximately 12,000 students, teachers, and families participated in more than 40 mathematics and science programs at the Center.

12-3. Students young and old enjoy the Quarks to Quasars interactive teaching station at Fermilab's Lederman Science Education Center, as evidenced by Nobel-winning physicist Leon Lederman's granddaughter, Jayna.

programs, with \$18.5 million for 1994. The Office of Minority Economic Impact, with its programs that encourage underrepresented minorities to pursue careers in science and technology, will have a total funding of \$2 million for 1994. Defense Programs will have, for the first time, identified funds that support education programs; its contribution for 1994 will be \$20 million.

The Department's education budget priorities for 1994 are consistent with and supportive of the National Education Goals prepared by state governors in a committee chaired by then-Governor Clinton. The Department's budget is also consistent with the priorities of the Committee on Education and Human Resources of the Federal Coordinating Council for Science, Engineering, and Technology.

University Research Support and Science Education

Under the University and Science Education Program, the Department provides support for a series of special-purpose research activities and science education projects. This program provides opportunities for hands-on research experiences at major laboratories for precollege, undergraduate, graduate, and postdoctoral students. For example, the Hands-On Universe program (Figure 12-4) was developed by the Lawrence Berkeley Laboratory for high school astronomy students.

Traditionally, University and Science Education Program activities have been multidisciplinary in nature, focusing on building and maintaining a national pool of outstanding scientists and engineers. Activities supported by this program fall into two general categories—those

12-4. Hands-On Universe, a program for high school astronomy students developed by the Lawrence Berkeley Laboratory, was demonstrated at the annual National Science Teachers Association meeting in Kansas City. This program is also featured at museums and science technology centers.

involving science education activities at the departmental laboratories and those directly supporting university projects and activities. A healthy university system that can expand the scientific knowledge base and cultivate new technical talent is critical to both national security and economic growth. The Department considers its support of this program an essential investment in the future.

Supporting Programs

Laboratory Cooperative Science Education Program

Through the Laboratory Cooperative Science Education Program, students and teachers gain firsthand knowledge of state-of-the-art research techniques and instrumentation developed at the national laboratories. Their summer or semester-length participation in research at departmental laboratories fosters intellectual growth for the academic community as well as for Department-supported research scientists and engineers. All national laboratories and research facilities support and provide science education, but seven—Argonne, Brookhaven, Oak Ridge, Los Alamos, Lawrence Berkeley, Pacific Northwest, and the Fermi National Accelerator Laboratory—also have been designated as departmental Science Education Centers; these laboratories conduct comprehensive precollege outreach and university-level science education programs.

During 1992, approximately 2,000 faculty, undergraduate, and graduate students participated in research-related education activities through this program at Department laboratories in the following areas: energy-related engineering, mathematical science; environmental, health, and life sciences; and the physical sciences. Approximately the same number were supported during 1993.

Science and Engineering Research Semester Program

Through the Science and Engineering Research Semester Program, outstanding undergraduate science and engineering students are competitively selected on a national basis for semester-length appointments at one of seven departmental national laboratories. At each participating national laboratory—Argonne, Brookhaven, Lawrence Berkeley, Lawrence Livermore, Los Alamos, Oak Ridge, and Pacific Northwest—participants work directly with laboratory scientists, using advanced equipment in hands-on research. During 1992 and 1993, some 400 students annually participated in the program.

High School Science Student Honors Research Program

Under the High School Science Student Honors Research Program, the best-qualified high school science and mathematics students, nominated by state governors, spend 2 weeks in the summer at the Department's national laboratories, where they research actual topics and present their findings to peers. Argonne, Brookhaven, Fermilab, Lawrence Berkeley, Lawrence Livermore, Oak Ridge, and Sandia participate in this program. More than 360 students, approximately 40 percent women or minorities, participate each summer, representing the 50 states, the District of Columbia, Puerto Rico, American Samoa, and several foreign countries.

Teacher Research Associates Program

Each year, more than 250 middle school and high school teachers enrich their classroom curriculum planning under the Teacher Research Associates Program, an 8-week training program on current technical topics. Since 1988, more than 20 national laboratories and facilities have participated in this program, which includes seminars, tours, and materials development experiences. The program offers selected teachers research stipends, housing and travel supplements, and, in some cases, academic credit. Teachers may apply directly to the program or be nominated by their state science supervisor.

Prefreshman Enrichment Program

Under the Prefreshman Enrichment Program, participating institutions, primarily colleges and universities with science-based degree programs, conduct summer institutes for students in grades 6 through 10. The summer activities focus on encouraging students, including women and minorities, to consider careers in science-related fields. By guiding students to choose college-preparatory science and mathematics courses, the program aims to capture and keep students' interest in science. Enrichment experiences provided by the program include laboratory work, field trips, tutoring, and counseling. Institutions are encouraged to share the cost, using university, industrial, or other non-Federal support. This program, which reaches approximately 6,000 students each summer, is one national precollege initiative that is not laboratory-based.

University Research Instrumentation Program

The objective of the University Research Instrumentation Program is to help universities and colleges acquire specialized research instrumentation for long-range, energy-related research. During 1992, the program made 25 awards, totaling \$5.6 million, to universities throughout the country; 24 awards, totaling \$5.2 million, were made in 1993. Awardees are selected on technical merit from responses to an annual solicitation for applications.

Used Energy-Related Laboratory Equipment Grant Program

The Used Energy-Related Laboratory Equipment Grant Program makes available to colleges and universities laboratory equipment purchased by the Department for research but no longer needed by departmental facilities or contractors. Equipment ranges from power supplies, oscilloscopes, data recorders, amplifiers, and voltmeters to more sophisticated special-purpose items, such as infusion pumps, borescopes, and ion power supply pumps. Available equipment is listed monthly in a catalog available by subscription from the U.S. Government Printing Office and in a dial-up computer data base. The program operates on a "first-come-and-qualified" basis, with crating and shipping the only expenses the recipient incurs. Title to the equipment is vested in the receiving institution. In 1992, 395 grants were awarded involving 712 individual pieces of equipment. Through September 1993, 304 grants were awarded, involving 722 individual pieces of equipment.

University Reactor Fuel Assistance Program

For more than 25 years, university-based reactors have played a prominent role in the Nation's training and research in nuclear science and engineering as well as in chemistry, physics, geology, biology, and materials sciences. Currently, 33 university research and training reactors are operating in the United States. Under the University Reactor Fuel Assistance Program, the Department lends universities fuel to operate these reactors and provides funding for fabricating fuel elements. In addition, the Department provides reactor-sharing grants to universities that make their reactors and analytical facilities available to educational institutions lacking such resources.

Manpower Assessment Program

To ensure that the Nation's energy policies will not be impeded by future shortages of scientists and engineers, the Manpower Assessment Program monitors and assesses many factors that affect the supply of and demand for persons in various disciplines. Comprehensive assessments and surveys—covering supply-and-demand trends in energy-related science and engineering fields—have identified shortages in several fields, including health physics, nuclear engineering, accelerator physics, several environmental and earth science specialties, computer science, petroleum engineering, materials science specialties, mechanical engineering, and electrical and electronic engineering.

Initiatives and Partnerships

Many of the Department's mathematics and science education initiatives are implemented through partnerships with schools, businesses, museums, and other entities that offer expertise, support, and a link from the education community to the Department's staff and resources. In addition to broadened program outreach, the Department has signed, with other Federal agencies and with private-sector organizations, memoranda of understanding that will be implemented in conjunction with the Department's national laboratories and facilities. Several of these education initiatives are described below.

Teachers Teaching Teachers Program

Offered by Idaho National Engineering Laboratory, the Teachers Teaching Teachers Program carries two credits from Idaho State University. In this program, master teachers conduct hands-on experiments with 50 elementary schoolteachers who are enriching their backgrounds in math and science to meet their students' needs. A laboratory survey verified the need for this program. Results showed that 80 percent of elementary schoolteachers had never taken a physics or chemistry course, and their lack of training, supplies, and equipment made teaching science and mathematics to their students difficult and intimidating.

Becoming Enthusiastic About Math and Science Programs

The Becoming Enthusiastic About Math and Science Program augments the science and mathematics curriculum

of the Newport News, Virginia, public schools by enabling fifth and sixth grade students to spend 5 entire, consecutive school days at the Continuous Electronic Beam Accelerator Facility. There, 50 volunteer facility scientists, engineers, and technicians conduct hands-on science and mathematics activities with more than 175 students and 7 teachers. On the fourth night, students' family members and friends are invited to tour the facility and share what the students have learned by participating with them in the activities.

Bay Area Science and Technology Educational Collaboration

The Bay Area Science and Technology Educational Collaboration is a multilaboratory, regional partnership designed to improve science, mathematics, and technology education in kindergarten through 12th grade in the Oakland Unified School District, Oakland, California. Partners include business and industry, universities, community-based organizations, and four national laboratories—Lawrence Berkeley (the lead laboratory), Lawrence Livermore, the Stanford Linear Accelerator Center, and Sandia-Livermore. Together, the partners are responsible for developing and implementing a comprehensive reform (in compliance with state guidelines) of kindergarten through 12th-grade science, mathematics, and technology curriculums. The partners also coordinate professional development through summer workshops and research participation for teachers in the Oakland Unified School District, as well as loan equipment and make grants for their classrooms. Schools in the district also use the laboratories for field trips and similar activities.

The New Explorers

The New Explorers, now in its third season on the Public Broadcasting System, is a television series that presents the personalities and interests of scientists at work. It focuses on the research of these "new explorers," who are on the cutting edge of scientific discovery and are extending the frontiers of science, nature, and environmental conservation (Figure 12-5).

Produced by WTTW, the Public Broadcasting System affiliate in Chicago, the series is underwritten by Amoco Corporation, Waste Management, Inc., and Duracell. The Department supports the development and collaboration for educational support for the series through the National Science Explorers Program.

12-5. For *The New Explorers*, a Public Broadcasting System television series in its third year, Argonne National Laboratory worked with other partners to develop the accompanying teachers guides for each video. This model partnership with teachers and scientists has been replicated nationwide.

During the summer of 1992, it became apparent that museums and zoos from other cities would be interested in participating in the New Explorers Program. The interest arose because of presentations and articles written for the Association of Science Technology Centers, American Association of Museums, Association of Zoological Parks and Aquariums, and Association of Youth Museums. To date, this interest has resulted in expansion to Boston, Massachusetts, Cincinnati, Ohio, Knoxville, Tennessee, Somerville, New Jersey, and Washington, D.C. Further expansions are in various stages of development.

SCIENCE AND TECHNOLOGY INFORMATION MANAGEMENT

Introduction

To support national competitiveness, the Department has continued to use its base of scientific and technical information to transfer science and technology to U.S. industry. During 1992, DOE provided public availability through the Department of Commerce National Technical Information Service, Government Printing Office depository libraries, the Library of Congress, and commercial information distributors. More than 24,000 full-text documents and 184,000 DOE and worldwide energy research summaries bring the cumulative total to nearly 3 million summaries already in the data base. DOE also acquired in 1992 approximately 88,000 summaries of foreign scientific and technical information and provided access to U.S. industry. The Department fostered the development of cooperative research and development agreements, which enable U.S. industry to benefit from collaborative relationships with the government sector and to successfully commercialize high-risk technologies. Through the use of management information systems, the Department ensured maximum government and industry benefit from the cooperative research and development agreements process.

Education Support

The Department supported science, mathematics, and engineering education through a program designed to promote the interests of kindergarten, elementary, and secondary-grade children in these disciplines. Educational

materials and other energy-related information were disseminated to teachers, students, and the general public through both targeted and on-demand procedures. The Department developed and distributed the *DOE Education Programs Catalog*, which describes educational programs and opportunities available from DOE facilities to teachers, school administrators, and students. DOE also revised, published, and disseminated nationwide the *Science Activities in Energy* workbook series, consisting of 14 packets of science experiments and activities for use in the classroom.

Other Activities

In the area of environmental protection and waste management, DOE developed information management systems for the rapidly expanding information from corrective plans, emerging waste management technologies, and environment, safety, and health reviews. The Department also assumed a leading role in the Interagency Working Group on Data Management for Global Change. Easy access to, and rapid exchange of, global change data were promoted through DOE's testing of a Wide Area Information Server, using a 5,000-record global change data set.

The Department initiated a strategic planning process for the development of accepted DOE-wide standard operating guidelines for electronic document format and exchange, which encompasses electronic publishing, hardware, software, telecommunications, and data-specific standards. DOE also pushed ahead on the departmentwide adoption and implementation of Standard Generalized Markup Language for the uniform electronic transmission of information.

CHAPTER 13

LABORATORY MANAGEMENT

LABORATORY SYSTEM

The Department of Energy laboratory system comprises 28 research and development facilities that are federally owned and mostly operated for the Department by universities, university consortia, or industrial contractors. It is the largest laboratory system of its kind in the world. Table 13-1 lists the Department's laboratories; Figure 13-1 is a map of the laboratories. Nine of the laboratories are considered major multiprogram laboratories. These are large, diversified facilities that receive funding from several program offices. Program-dedicated laboratories tend to be smaller than multiprogram laboratories, have a single research focus, and receive their funding predominantly from one program office within the Department. Specific mission laboratories also work primarily for one program office, but are typically smaller and have an even more focused mission than program-dedicated laboratories.

The laboratories have been a major source of scientific creativity and innovation. Eighteen Nobel laureates performed prize-winning research while on the staff of a Department of Energy national laboratory, and 13 additional Nobel laureates used facilities at the laboratories in their award-winning discoveries. In addition, the Department has won more "R&D 100" awards than any other Federal agency or private company.

The combined laboratories have the core competencies and capabilities to carry out missions for all Department of Energy programs and to undertake new or expanded missions to meet national research and development needs in support of other agencies. The laboratory system operates as a national resource that can enter into partnerships with industry, universities, and state and local governments

to meet future scientific and technical challenges and opportunities in support of technology transfer. As a national resource, the Department of Energy laboratory complex represents a significant potential for performing a major role in enhancing U.S. economic competitiveness.

Researchers from universities and industry have access to the large, unique facilities within the laboratory system for their own research or collaborative efforts. Peer review of proposals for experimental use of facilities helps maintain the high quality of science performed by the staff and by university and industry researchers at the Department's laboratories. Laboratories provide significant hands-on support to national and local education in science and mathematics at all scholastic levels. Laboratories also offer special training and research opportunities to graduate students, professors, and other scientists and engineers in many disciplines.

The research being accomplished at the laboratories ranges from the most basic studies of the ultimate constituents of matter to addressing highly complex, applied research and engineering problems—not only in areas of energy and defense, but also in high-performance computing, biotechnology, advanced manufacturing, materials, and waste minimization. The capabilities of the Department's laboratories have allowed the Department to serve the Nation in such areas as increasing the efficiency of energy utilization; developing domestic energy resources; enhancing environmental quality; contributing to basic sciences, mathematics, and engineering; enhancing the Nation's industrial and manufacturing competitiveness; and investing in human resources.

Secretary O'Leary, in her reorganization plan announced in April 1993, consolidated responsibility for planning,

Table 13-1—DOE laboratory complex statistics

Laboratory	Contractor	Location	Year Established	FY93 \$Millions	Full Time Equivalent
Multiprogram Laboratories					
Argonne National Laboratory	University of Chicago	Chicago, Illinois	1946	480	4,859
Brookhaven National Laboratory	Associated Universities, Incorporated	Upton, New York	1947	322	3,532
Idaho National Engineering Laboratory	Westinghouse, Rockwell, EG&G, Prot. Tech.	Idaho Falls, Idaho	1949	611	7,251
Lawrence Berkeley Laboratory	University of California	Berkeley, California	1931	226	2,646
Lawrence Livermore National Laboratory	University of California	Livermore, California	1952	958	7,200
Los Alamos National Laboratory	University of California	Los Alamos, New Mexico	1943	1,018	7,450
Oak Ridge National Laboratory	Martin Marietta	Oak Ridge, Tennessee	1943	802	5,474
Pacific Northwest Laboratory	Battelle Memorial Institute	Richland, Washington	1965	415	3,997
Sandia National Laboratories	Martin Marietta	California and New Mexico	1949	1,299	8,550
Program-Dedicated Laboratories					
Ames Laboratory	Iowa State University	Ames, Iowa	1947	38	505
Continuous Electron Beam Accelerator	Southeastern University Research Association, Incorporated	Newport News, Virginia	1986	29	497
Fermi National Accelerator Laboratory	University Research Association, Incorporated	Batavia, Illinois	1968	168	2,319
Morgantown Energy Technology Center	U.S. Department of Energy	Morgantown, West Virginia	1946	425	314
National Renewable Energy Laboratory	Midwest Research Institute	Golden, Colorado	1977	114	645
Oak Ridge Institute for Science and Education	Oak Ridge Associated Universities	Oak Ridge, Tennessee	1946	64	683
Pittsburgh Energy Technology Center	U.S. Department of Energy	Pittsburgh, Pennsylvania	1944	296	320
Princeton Plasma Physics Laboratory	Princeton University	Princeton, New Jersey	1951	110	1,038
Savannah River Technology Center	Westinghouse	Aiken, South Carolina	1951	193	967
Stanford Linear Accelerator Center	Stanford University	Stanford, California	1962	139	1,581
Super Conducting Supercollider Laboratory	Universities Research Association, Incorporated	Dallas, Texas	1989	100	2,400
Specific-Mission Laboratories^a					
Energy Technology Engineering Center	Rockwell International	Canoga Park, California	1966	35	147
Environmental Measurements Laboratory	U.S. Department of Energy	New York, New York	1947	10	89
Inhalation Toxicology Research Institute	Lovelace Institute	Albuquerque, New Mexico	1960	14	185
Laboratory of Biomedical and Environmental Sciences	University of California	Los Angeles, California	1947	11	183
Laboratory of Radiobiology and Environmental Health	University of California	San Francisco, California	1951	3	49
National Institute for Petroleum and Energy Research	IIT Research Institute (BDM, Incorporated on 1/94)	Bartlesville, Oklahoma	1918	11	152
New Brunswick Laboratory	U.S. Department of Energy	Argonne, Illinois	1949	4	43
Savannah River Ecology Laboratory	University of Georgia	Aiken, South Carolina	1951	10	165
Totals				7,998	63,241

Note: FY93 dollars are estimates based on budget projections in institutional plans.

^aExcludes Bettis and Knolls Atomic Power Laboratories under 42 USC 7158.

◎ SPECIFIC-MISSION LABORATORIES

Energy Technology Engineering Center, CA
 Environmental Measurements Laboratory, NY
 Inhalation Toxicology Research Institute, NM
 Laboratory of Biomedical and Environmental Sciences, CA
 Laboratory of Radiobiology and Environmental Health, CA
 National Institute for Petroleum and Energy Research, OK
 New Brunswick Laboratory, IL
 Savannah River Ecology Laboratory, SC

■ MULTIPROGRAM LABORATORIES

Argonne National Laboratory, IL
 Brookhaven National Laboratory, NY
 Idaho National Engineering Laboratory, ID
 Lawrence Berkeley Laboratory, CA
 Lawrence Livermore National Laboratory, CA

Los Alamos National Laboratory, NM
 Oak Ridge National Laboratory, TN
 Pacific Northwest Laboratory, WA
 Sandia National Laboratories, NM

● PROGRAM-DEDICATED LABORATORIES

Ames Laboratory, IA
 Continuous Electron Beam Accelerator Facility, VA
 Fermi National Accelerator Laboratory, IL
 Morgantown Energy Technology Center, WV
 National Renewable Energy Laboratory, CO
 Oak Ridge Institute for Science Education, TN
 Pittsburgh Energy Technology Center, PA
 Princeton Plasma Physics Laboratory, NJ
 Savannah River Technology Center, SC
 Stanford Linear Accelerator Center, CA
 Super Conducting Supercollider Laboratory, TX

oversight, and coordination of policies and issues into a new Office of Laboratory Management.

MANAGEMENT OVERSIGHT

The laboratory system's management structure involves the Department of Energy Headquarters, Operations Offices, and the contractors operating the Government-owned, contractor-operated (GOCO) laboratories. Overall, management oversight of each program-dedicated and specific mission laboratory is the responsibility of the secretarial officer with major programmatic activities carried out at a laboratory. Additionally, the cognizant program secretarial officer with major programmatic work at a laboratory plays a major role in overseeing the institutional

management of each laboratory (Table 13-2). The Office of Laboratory Management manages a departmentwide process that applies uniformly to all of the major Department of Energy laboratories. The Operations Offices are responsible for contract management and administration and day-to-day oversight of operations at the laboratories. They carry out for the Office of Laboratory Management, the annual laboratory appraisals, and the Laboratory-Directed Research and Development program and oversee the Work for Others Program, under which laboratories provide services to organizations other than DOE.

The Office of Laboratory Management provides the focus for crosscutting responsibilities for institutional policy, planning, and oversight of the Department's laboratory complex. The office is responsible for the laboratories' policy, planning, utilization, and general oversight and appraisal processes for the research and development complex as a whole. Key objectives of this organization are to develop more effective utilization of the laboratory complex and to support the Administration's technology transfer initiatives to enhance the competitiveness of U.S. industry.

Secretary O'Leary also began initiatives to examine the role of the laboratories and change the way the Department interacts with them. She established a priority team made up of departmental and laboratory managers to examine the missions of the laboratories. The work of the team provided the Secretary with a framework for further policy discussion and analysis of the Department's laboratory complex. Recognizing the importance of building an effective working relationship based on openness and trust, the Secretary increased the involvement of the laboratories in the Department's management process. She increased the frequency of regular meetings among the Secretary, program secretarial officers, Operations Office managers, and laboratory directors. She also involved the laboratory directors as full participants with the Department's senior staff and operations officer managers in receiving quality management training at Motorola's total quality management institute.

In addition to coordinating the laboratory directors meetings mentioned above, the Office of Laboratory Management oversees and coordinates the laboratory Institutional Planning Process. Each multiprogram laboratory is required to develop an Institutional Plan that describes its strategic plan and integrates all other planning at the laboratory. The Institutional Plan is a comprehensive overview of a laboratory and describes laboratory initiatives for new facilities or programs. The plans include the

Table 13-2—Institutional oversight responsibility of multiprogram laboratories

Laboratory	Oversight responsibility
Lawrence Livermore National Laboratory	Assistant Secretary for Defense Programs
Los Alamos National Laboratory	Assistant Secretary for Defense Programs
Sandia National Laboratories	Assistant Secretary for Defense Programs
Idaho National Engineering Laboratory	Office of Nuclear Energy
Argonne National Laboratory	Director of Energy Research
Brookhaven National Laboratory	Director of Energy Research
Lawrence Berkeley Laboratory	Director of Energy Research
Oak Ridge National Laboratory	Director of Energy Research
Pacific Northwest Laboratory	Director of Energy Research

laboratory's mission and core competencies; 20-year strategic plan; issues; scientific initiatives; research programs; technology transfer; science education activities; environment, safety, and health activities; human resources; and facilities. Most importantly, the Institutional Planning Process ensures that major laboratories perform integrated planning for their entire facility and organization as a whole. Review and approval of the plan by the Department results in an agreement on the scope and level of work for the laboratory. The approved plan also represents the baseline document against which work assigned to the laboratory is compared to ensure it is appropriate for the institution.

Under the Work for Others Program, the resources of the Department's laboratories are made available to non-Department of Energy entities such as other Federal agencies, state and local governments, and private industry. This program encourages utilization of the Department's unique and highly specialized Government-owned, contractor-operated facilities and technical expertise to solve challenging advanced research and technology problems, and serves to avoid unnecessary duplication of capabilities. Through access to the scientific and technical facilities of the Department's laboratories, as well as direct partnerships, the program also supports technology transfer and industry's efforts to improve U.S. competitiveness. Benefits to the Department include enhancement of its core competencies through opportunities to apply technological advances to replenish its science and technology infrastructure.

The Laboratory-Directed Research and Development Program within the multiprogram laboratories provides funds for early exploration of new scientific and technological concepts that are selected by laboratories and are creative and innovative in nature for the purpose of maintaining the scientific and technological vitality of the laboratories. A small percentage of the laboratories' budgets is set aside for this purpose each year. This program has yielded substantive benefits in establishing new directions in scientific programs, revitalizing the innovativeness of laboratory personnel, and opening new areas of scientific investigation. Research areas subsequently supported as a result of this program have included high-temperature superconductivity, basic biological research, novel material processing techniques, and advanced environmental restoration technologies.

The annual laboratory performance appraisal is another management tool used by the Department to maintain laboratory management accountability and to determine and continually enhance the quality of the laboratories' work.

Annual appraisals measure laboratory performance in a number of areas, including specific program performance and general business management, as well as administration, health, safety, and environmental protection. These appraisals provide information on which to base decisions, such as whether to extend or compete the laboratories' management and operating contracts. These appraisals are an important part of the Department's system, which focuses on efficient processes and quality results, rewards initiatives and commitment, and provides meaningful disincentives where necessary.

MULTIPROGRAM ENERGY LABORATORIES-FACILITIES SUPPORT PROGRAM

The Multiprogram Energy Laboratories-Facilities Support (MEL-FS) Program addresses general-purpose infrastructure needs at five of the Department's multiprogram laboratories, that is, Argonne National Laboratory-East (ANL-E), Brookhaven National Laboratory (BNL), Lawrence Berkeley Laboratory (LBL), Oak Ridge National Laboratory (ORNL), and Pacific Northwest Laboratory (PNL). These Government-owned, contractor-operated laboratories are complete research reservations with land, buildings, utility systems, roads, and other support systems. The estimated cost of replacing the general-purpose facilities at the laboratories is \$7 billion. A portion of the laboratory infrastructure is old, deteriorating, and obsolete and is not in compliance with the environmental and safety and health (ES&H) requirements in effect today.

The research and development objectives of the Department dictate the continued extensive use of the laboratories far into the next century. The Multiprogram Energy Laboratories-Facilities Support program was established to preserve the Government's investment in infrastructure and to maintain infrastructure integrity in a reasonable, safe, environmentally responsible, and economic manner at the multiprogram energy laboratories. The program has two subprograms: General Purpose Facilities (GPF) and ES&H Support. These subprograms help to ensure the infrastructure of the laboratories is adequate to support the Department's missions.

The GPF subprogram provides funding for line-item construction projects that rehabilitate, renovate, upgrade, and replace general-purpose facilities at the laboratories. These facilities include general office and laboratory space,

utility systems, sanitary sewers, and roads. The 1993 GPF subprogram budget continued ongoing projects and initiated two new projects—a potable water system upgrade project at Brookhaven and an electrical system upgrade at Argonne.

The ES&H Support subprogram funds sitewide ES&H capital needs identified in the DOE ES&H Management Plan. Deficiencies accumulated over many years continue to represent a significant burden on current laboratory budgets. Funding for 1993 allowed the initiation of five new construction projects: fire safety improvements at Argonne-East, a roof replacement at Brookhaven, hazardous materials safeguards and fire- and safety-system upgrades at Lawrence Berkeley, and life safety code compliance actions at Pacific Northwest. Funding was also provided for capital equipment needs related to ES&H activities.

The program's investment in general-purpose facilities helps ensure that the national laboratories can conduct Department of Energy and other assigned missions in a cost-effective, efficient manner consistent with worker and public safety and environmental protection.

LABORATORY TECHNOLOGY TRANSFER PROGRAM

In addition to licensing, performing cooperative research, operating user centers, and engaging in other general technology transfer activities inherent in laboratory research programs, the Office of Laboratory Management supports one of the two departmental programs specifically designed to undertake collaborations based solely on industry need: the Laboratory Technology Transfer Program.

The primary mission of the Laboratory Technology Transfer Program is to collaborate with industry to employ the technology of these laboratories for the benefit of U.S. industry. The program's dedicated funding fulfills a legislative mandate to more effectively transfer research and technology from the civilian laboratories to industry. The program's focus is on spinoff technologies and fostering multilaboratory coordination for an integrated industry. (Spinoff is the further enhancement and application of technology developed by a Department of Energy research and development program for another purpose.)

The program is designed to support small startup spinoff projects—typically referred to as “seed projects”—with

particular emphasis on quick response and small business, individual spinoff cooperative research and development agreements (CRADAs) with industry partners, and large multilaboratory spinoff CRADA partnerships. Because the program's projects spring from industry's need for specific technologies, this has naturally shaped a portfolio of projects that directly addresses key issues of competitiveness, as the following example illustrates.

National Castings Seed Project

An investment of \$29,000 in a 1990 personnel exchange yielded a project that created 200 new jobs in the Chicago area. The Department intended the exchange, sponsored by a program between Argonne National Laboratory and Packer Engineering Co, Inc., to show the value of supercomputing to small businesses. Through the personnel exchange, Packer engineers worked with Argonne scientists to use a supercomputer to describe the behavior of complex mechanisms. In 1992, Packer used this knowledge to help National Castings, an employee-owned company that makes cast-metal products for railroads, mining, and the steelmaking industry, redesign a key part of freight car suspension undercarriages. The new design provides a soft-riding means to transport new automobiles by rail.

Before teaming up with Packer, National Castings had twice tried to design an undercarriage that met the new industry standards, and had been unsuccessful. Using technical knowledge they acquired from the Laboratory Technology Transfer Program personnel exchange with Argonne National Laboratory, Packer was able to provide National Castings with a model that allows changes in component design and calculates the forces and motions of all components. The new software even animates the model to simulate going up hills and over bumps to see how parts bounce and vibrate.

The new design has been an unqualified success. First of all, employment at National Castings' Cicero, Illinois, plant has risen from 250 to 450 employees, largely drawn from the inner city of Chicago. Secondly, the Department personnel exchange stimulated Packer to invest \$250,000 in employee time and effort to develop their software. This was a successful transfer of technology from the laboratory to a small business. In turn, the small business successfully commercialized the transferred technology through its collaboration with National Castings.

Laboratory Technology Transfer Cooperative Research and Development Agreements (CRADAs)

In 1992 the Laboratory Technology Transfer Program sponsored 36 new and 4 ongoing spinoff CRADAs and more than 50 personnel exchanges. CRADA partners involve small businesses, large businesses, industry associations and centers, and universities. More than 45 percent of the CRADAs are with small business partners, and many of the technologies being developed under the CRADAs are in critical technology areas. Some examples of spinoff CRADA activities funded in 1992 follow:

1. A new pumpable castable refractory developed by Magneco/Metrel, Inc., a small business, in conjunction with Argonne National Laboratory, may decrease costs in the ironmaking and steelmaking industries. Development of the new refractory led to substantial overseas sales and the addition of about 15 new jobs at Magneco's Illinois plant. A cost-shared CRADA funded by the program developed this technology, derived from research originally sponsored by the Office of Basic Energy Sciences.
2. The Glycine Nitrate Process developed at the Pacific Northwest Laboratory prepares ultrafine ceramic oxide powders used in the manufacture of ceramics, sensors, and solid oxide fuel cells. The program funded a cost-shared CRADA with Seattle Special Ceramics, Inc., a small business, to transfer this technology. Pacific Northwest Laboratory received an R&D 100 award for the technology and a 1993 Federal Laboratory Consortium Award of Excellence for the technology transfer achievement. The Pacific Northwest Laboratory developed the technology from research originating from the Offices of Fossil Energy and Basic Energy Sciences.
3. In the mid-1980s, an Oak Ridge National Laboratory development in crystal growth provided the technology that allowed Commercial Crystal Laboratories, Inc., a small business, to manufacture magnesium oxide crystals—a type of superconductor substrate that is useful in microwave electronics—and to reduce their price by 40 percent. This increased the overall market share for this crystal from an estimated 20 percent to an estimated 60 percent, and Commercial Crystal became the sole U.S. supplier for these crystals. Between 1989 and 1991,

the company's market share decreased to 5 percent because of a new technology developed by a Japanese competitor. The program funded a CRADA between Commercial Crystal Laboratories and Oak Ridge National Laboratory to develop new commercially viable methods for producing these crystals to enable the company to regain its market share and compete with foreign suppliers. The technology for this project originated from research from the Office of Basic Energy Sciences.

4. Lawrence Berkeley Laboratory and Seagate Magnetics Corp. of Fremont, California, a major manufacturer of computer disk drives, worked on a CRADA to improve Seagate's disk-drive technology and strengthen their market position. Seagate came to Berkeley for this effort because of their successful commercialization of another innovation resulting from an earlier collaboration, a personnel exchange that developed an improved coating process enabling Seagate to manufacture competitive hard-diskproducts.

The flexibility of the Laboratory Technology Transfer Program in addressing the needs of industry is exemplified by the American Textiles Consortium partnership, a model collaboration between the national laboratories and the U.S. textiles industry. Since 1978, close to 500,000 U.S. textile jobs have been lost to foreign competitors, which rely on inexpensive foreign labor for the manufacture of finished goods. The unified U.S. textiles industry approached the Department of Energy in response to a critical technologies workshop sponsored by the Laboratory Technology Transfer Program. Together, the program and industry developed a major multilaboratory, multi-industry participant, cost-shared partnership. On March 15, 1993, the Secretary and representatives of the U.S. textiles industry signed an agreement designed to address the technology concerns of all elements of the industry and to increase competitiveness. Topics covered ranged from fiber production to material fabrication to the manufacture and distribution of consumer goods. Key technology development areas included improved materials and processes; analysis, simulation, and computer integration; environmental quality and waste minimization; reduction of energy costs and improvement of energy efficiency; and apparel automation.

In 1993, the program grew and enhanced the support of spinoff CRADAs and multilaboratory spinoff partnerships such as the American Textiles Consortium and small start-up spinoff projects—particularly with small business.

CHAPTER 14

TECHNOLOGY TRANSFER

INTRODUCTION

New government priorities regarding technology transfer and the Department are resulting from post-cold war realities. The Department has taken decisive action to help the United States create new jobs, compete in the global marketplace, protect the environment, and reinvent the Federal Government while maintaining national security.

Through technology transfer and cooperative research and development (R&D) relationships with the private sector, the Department's goal is to ensure that its laboratories' and facilities' unique capabilities are applied to achieving important national goals, including economic growth, energy efficiency, and environmental protection.

The Department's remarkably diverse national laboratories and facilities now offer U.S. industry exciting new opportunities to create jobs for citizens. With the end of the cold war, the national agenda is changing, and the focus is shifting to solving domestic problems. The Department's technology transfer programs can help sharpen America's technical edge in world markets.

As will be shown in this chapter, the National Competitiveness Technology Transfer Act and other related legislation and departmental initiatives are having a significant impact by encouraging increased contributions of the Department and its laboratories to U.S. economic competitiveness.

This chapter is organized into three parts: a description of the Department's Technology Transfer Program, a report on the program for 1992, and plans for the technology transfer function for 1993. This section also provides a summary of representative activities in several critical

technology areas where the Department is committed to increased accomplishment in the years to come.

DEPARTMENT OF ENERGY'S TECHNOLOGY TRANSFER PROGRAM

During 1992, the Department's goals for its Technology Transfer Program paralleled those of the National Energy Strategy and were to increase the level of U.S.-based industry participation in the Department's R&D in all stages of program development and execution; increase the level of departmental program and laboratory activity in transferring technology, consistent with other program missions and authorities; and accelerate the process of transferring technology and knowledge to U.S.-based private industry as well as state and local governments. To support these goals, the Department made a number of changes and improvements in its management of technology transfer during 1992. These are summarized in the following paragraphs.

Technology Transfer Clause

The Department continued its efforts to incorporate a technology transfer clause into the management and operating contracts for its Government-owned, contractor-operated laboratories and facilities. As required by the

National Competitiveness Technology Transfer Act of 1989, these clauses establish clear and consistent guidelines implementing the laboratory and facility technology transfer activities, including conflict of interest, fairness of opportunity, accountability and oversight, and enhancing U.S. competitiveness. The Department has modified a total of 20 Government-owned, contractor-operated laboratory contracts—one during this reporting period. Negotiations continue for the remaining laboratory contractor, Westinghouse. The Department modified the first four nonlaboratory facility contracts during the reporting period and is continuing negotiations with the remaining two contractors.

Budgeting and Staffing

The Department continued to increase the budgeting and staffing levels related to the Laboratory Technology Transfer Program. Total budgets allocated to support the technology transfer process at the laboratories increased from \$50.1 million in 1991 to \$107.5 million in 1992. The latter figure is congruent with the 1993 figure of \$208.8 million shown on page 45 of the *Department of Energy Fiscal Year 1994 Budget Highlights* and as further discussed on page 54 of that document. The Environmental Restoration and Waste Management line item, Technology Integration, increased from \$7.2 million in 1991 to \$9.5 million in 1992. The Defense Programs Technology Transfer Initiative increased from \$20 million in 1991 to \$50 million in 1992, and the Energy Research Technology Transfer Program increased from \$2.6 million in 1991 to \$10 million in 1992. In addition to these line items, funding for technology transfer oversight (primarily an overhead expense) increased from \$20.4 million in 1991 to \$22.1 million in 1992. Of this latter figure, \$17.9 million was for the Offices of Research and Technology Assessment located at each of the 28 departmental laboratories. The remainder of the \$22.1 million was for intellectual property management and other overhead costs such as procurement, general legal counsel, public affairs, and financial services. The laboratory staffing levels related to the management and oversight of the technology transfer program also increased, from 132 full-time equivalents in 1991 to 139 full-time equivalents in 1992. In addition to this, the three applied energy programs (Energy Efficiency and Renewable Energy, Fossil Energy, and Nuclear Energy) have technology transfer as a key aspect of their base programs and do not show technology transfer as separate line items. Inclusion of key aspects of these

programs as technology transfer would greatly increase the level of technology transfer spending shown for the Department. Inclusion of nonlaboratory technology transfer activities, such as the Clean Coal Technology Program, would further increase total departmental 1993 technology transfer funding to the level of \$923 million as presented in the Secretary's April 1993 press briefing.

Education and Training

The Department's emphasis on education and training has continued with the development of a pilot, 1-day Enhanced Technology Transfer Program General Awareness Course for Department personnel for initial presentation and fine-tuning in January 1993, before being made available to Department program offices and staff offices for their use. The course was offered during 1993 at Headquarters and in the field with an average of 25–30 persons per session.

Implementation of Cooperative Research and Development Agreements

The Department has continued to refine and upgrade its "tools" available to help the Department and management and operating contractor employees implement the process for entering into cooperative research and development agreements (CRADAs). In December 1991, the Department issued to its laboratories and field offices a revised model CRADA and guidelines for its use. DOE based the revisions on comments received from the laboratories and field offices as discussed during the Department's October 1991 CRADA workshop. Based on experience with this baseline model during 1992, the Department recently issued further updates to its model CRADA and guidelines. These further revisions, designed to make the Department's process more in line with industry practice, addressed product liability issues raised in CRADA negotiations. In April 1992, the Department finalized a tailored model CRADA in cooperation with the Computer Systems Policy Project that recognizes the particular dynamics and competitive conditions of the U.S. computer industry. In June 1992, 5 departmental laboratories entered into an umbrella CRADA with the National Center for Manufacturing Sciences, a group of approximately 150 manufacturing companies ranging in size from small businesses to Fortune 500 companies. The use of

these tailored instruments is speeding and easing the negotiation and approval process for classes of CRADA participants.

Disadvantaged Businesses

The Department has continued its strong statutory commitment to working with and transferring technology to small and disadvantaged business. Of the 244 CRADAs executed as of the end of 1992, 61—or 25 percent—were with small business. One specific result of this continuing commitment is that Argonne National Laboratory has executed three of its eight extant CRADAs with small businesses and is now negotiating another seven CRADAs with small businesses. In addition, Ames Laboratory is participating in a project, sponsored by the Federal Laboratory Consortium and conducted by the National Association of Management and Technical Assistance Centers, to couple the laboratory with the Iowa State University Center for Industrial Research and Service to transfer Ames' technologies to Iowa small businesses. Foundries have been targeted as the first group of technology transferees for this project. Another outgrowth of this commitment is that during the 5th years that Los Alamos has had a formal technology licensing program, 18 of its 19 negotiated licenses have been with small businesses.

National Technology Initiative

The Department greatly increased its outreach to U.S. industry through the implementation of the National Technology Initiative (NTI), launched in January 1992. The purpose of NTI was to promote U.S. industry's use of technology to strengthen the domestic economy and to compete in global markets. A total of 15 conferences were held around the country kicked off by a series of regional conferences held in 1992 and designed to engage industry; university; and Federal, state, and local government representatives in a dialogue on ways to more rapidly commercialize federally funded technology. The conferences were cosponsored by the Department of Energy, the Department of Commerce, the Department of Transportation, and the National Aeronautics and Space Administration, and included the participation of the Department of Health and Human Services, the Department of Agriculture, and the Environmental Protection Agency. The sponsors held 15 conferences through December 1992.

The first 10 brought together more than 3,500 representatives, principally from high-technology industry, Federal laboratories, universities, and government, in a series of technologically focused meetings. Each conference focused on three principal topics that affect the cost and speed of innovation: cooperative research and development; financing technology research, development, and commercialization; and manufacturing excellence. As an outgrowth of NTI, the Environmental Protection Agency and the Department held three joint workshops on environmentally beneficial technology in September 1992.

Industry Partners Feedback

The Department held an Industry Partners Feedback meeting on November 12, 1992, to evaluate departmental relations with industry and university technology transfer partners. The meeting aimed to receive feedback from departmental partners for the purpose of identifying opportunities to improve the departmental cooperative work processes with the private sector and with universities. The Department designed the meeting to collect information, which was then discussed at the internal Technology Transfer Process Workshop, as action items to improve private sector and university partnerships with the Department.

Technology Transfer Process Workshop

The Department held an internal Technology Transfer Process Workshop on December 8–10, 1992, to evaluate its own technology transfer processes throughout laboratories, operations offices, and Headquarters elements. The purpose of the meeting was to share technology transfer experiences, ideas, and lessons learned in 1992, to consider important industry input received at the Industry Feedback Meeting of November 12, 1992, and to arrive at some conclusions about ways to continue to improve the departmental technology transfer process at the Department of Energy. Participants compiled an extensive list of action items and issues for further work based on the work done in smaller groups and views expressed by industry partners at the Industry Partners Feedback Meeting. These items ranged from the drafting of policy clarification on U.S. competitiveness to the need for internal and external newsletters on departmental technology transfer.

LABORATORY TECHNOLOGY TRANSFER PROGRAM

The Department continues to see significant signs of success of its Enhanced Technology Transfer Program. A variety of measures can be used to describe laboratory accomplishments and efforts in technology transfer during 1992. Two hundred new CRADAs were approved; 432 new U.S. patent applications were submitted; 215 licenses were awarded; licensing income reached \$2,369,000; and 5 new companies were formed. These measures are far from complete in describing departmental laboratory contributions to the U.S. economy. However, the data provide a representative sample.

Laboratory funds allocated to technology transfer include those allocated to the Offices of Research and Technology Applications, intellectual property management, and other indirect costs such as procurement, general legal counsel, public affairs, and financial services. In 1992, departmental allocations to its laboratories were \$22,139,000 to technology transfer and \$17,944,000 to the Offices of Research and Technology Applications offices, which reside at several laboratories.

One of the most visible signs of continuing success has been the rapid growth in industry interest in working with the Department's laboratories through CRADAs. The number of CRADAs approved involving departmental laboratories increased from 44 at the end of 1991 to 244 as of the end of 1992, as shown in Figure 14-1. The data therein show a significant increase in the rate of CRADA execution and approval, starting in April 1992. This rate went from 7 to 11 per month in October 1991 through May 1992 to 16 to 29 per month in June through September 1992. This sharp increase in the rate of CRADA execution and approval lags the start of NTI by 3 months. The growth in two other annual indicators (U.S. patent applications and licenses awarded) is equally impressive. Figures 14-2, 14-3, and 14-4 show data for the last 4 years for each of these measures of accomplishment, as well as for license income.

As can be seen from the figures, over the past 3 years, U.S. patent applications have increased 13 percent, licenses awarded have increased 320 percent, and income from licenses has increased 84 percent. There has been some year-to-year unevenness caused by expiration of some patents on which royalties were being received, the effect of one-time, upfront royalties, and the maturity and de-

14-1. DOE CRADA approval.

14-2. License income, 1989-92.

14-3. U.S. patent applications, 1989-92.

14-4. Licenses awarded, 1989-92.

creased sales of some commercialized products for which running royalties are being received as a percentage of sales. The recession may also have played a role in sales decreases. Often, running royalties are not received until years after the patent is licensed. In addition, and compared with last year's license income information, updating 1991 data for two laboratories has resulted in a decrease in the total of license income recorded for that year.

The number of new companies formed based on laboratory technologies decreased, possibly reflecting the effect of the recession. Even with this downturn, departmental laboratories have reported the formation of over 130 new companies based on laboratory technologies since 1987.

The technology from departmental laboratories now available to U.S. industry includes 28 winners of the prestigious R&D 100 Awards given in 1992 by *R&D Magazine* for the 100 most significant new inventions in America. Department of Energy inventors won 27 of these awards in 1990 and 36 in 1991. These awards to departmental laboratory inventors reflect the continued superior performance of departmental laboratories in producing cutting-edge results from their research projects. Having won more than 300 of these awards, departmental laboratory inventors have received more than have inventors of any other organization since the awards program began in 1963.

LABORATORY-TO-INDUSTRY TECHNOLOGY TRANSFER

Examples of technologies and assistance provided to U.S. industry by departmental laboratories in 1992 cover the breadth of R&D activities supported by this Department. A partial listing of examples follows in the areas of energy, environmental technologies, advanced materials, advanced manufacturing, biotechnology, and high-performance computing.

Energy

Under Office of Energy Efficiency and Renewable Energy sponsorship, the Lawrence Berkeley Laboratory has signed a CRADA with the U.S. Advanced Battery Consortium to develop advanced batteries for electric vehicles. Successful development and implementation of lithium-polymer batteries in electric vehicles would significantly

increase their cost-effectiveness, increasing the likelihood of significant penetration of electric vehicles into the U.S. transportation fleet. The partnership will perform product and process development work on these advanced batteries to improve battery price-performance parameters, develop an economic commercial-scale battery production process, and determine capital and manufacturing cost parameters for the battery production process.

The National Renewable Energy Laboratory, under Office of Energy Efficiency and Renewable Energy sponsorship, has signed a CRADA with Amoco aimed at pilot-scale development and demonstration of a process for the enzymatic hydrolysis-augmented conversion of the cellulose in wastepaper to ethanol. If proven commercially feasible, this technology could result in enhanced process economics for the production of ethanol as an alternative motor fuel.

In 1992, under Office of Fossil Energy sponsorship, the Oil Recovery Technology Partnership initiated three new projects after industry review of candidates. This partnership is the primary means of transferring national laboratory technology to the U.S. oil industry. It is aimed at increasing domestic production by upgrading oil field exploration and production technology. The three new partnership projects initiated in 1992 include investigation of the feasibility of using titanium pipe and tool joints in drilling applications (Los Alamos, Texaco, Exxon, Conoco, Titanium Technologies, Inc., RMI Titanium Company, and Stress Engineering Services), fluid placement in horizontal and deviated wells (Los Alamos and Marathon Oil Company), and the use of expanded metal packers for permanent zone isolation in horizontal wells (Oryx Energy Company and Los Alamos).

Under Office of Fossil Energy sponsorship, the Pittsburgh Energy Technology Center entered into a CRADA with Rocket Research Company to evaluate an arc-plasma device that could result in a more cost-effective method for reducing nitrous oxide emissions from coal-burning boilers. The Pittsburgh Energy Technology Center has also licensed its Micro-Mag minerals separation process for producing low-ash, low-sulfur coal products to Custom Coals International, which is currently commercializing the technology.

Environmental Technologies

Pacific Northwest Laboratory (PNL) technology has led to the formation of a spinoff company, Viatec/Recovery Systems, in conjunction with Viatec, Inc. The new com-

pany will commercialize a PNL technology, the Waste Acid Detoxification and Reclamation process, which won an R&D 100 Award in 1991. This technology is a recovery-and-recycle approach to treating metal-bearing acid waste streams. These streams are created by companies, such as platers, that are under increasing regulatory pressure to adopt more effective means of waste minimization or disposal. This collaboration is facilitated by a staff exchange between PNL and Viatec.

Under Office of Energy Efficiency and Renewable Energy sponsorship, the National Renewable Energy Laboratory and Argonne National Laboratory have signed a CRADA with Otter Tail Power Company, Green Isle Environmental Services, and XL Disposal. The purpose of this CRADA is to develop a process for making small fuel pellets from ordinary household garbage found in landfills. The partnership envisions that these pellets can then be burned in combination with coal in utility powerplants. This development offers potential for extending the life of municipal landfills.

Under Office of Environmental Restoration and Waste Management sponsorship, Ames Laboratory and Layne Environmental Services, Inc., a small business, signed a CRADA aimed at the development of new methods for the remote characterization of subsurface contaminants. This should in turn add to the technology available for evaluation and remediation of contaminated underground sites. The technology involves drilling techniques developed by Layne and advanced underground probes and analytical techniques developed by Ames. No removal of subsurface samples is necessary, and there is no need for drilling mud or other conventional approaches that lead to surface exposure of subsurface contaminants.

The Idaho National Engineering Laboratory Center for Biological Processing Technology signed a CRADA with EG&G Rotron Industrial Division of Saugerties, New York, to develop biofilters for the treatment of contaminated vapor and gas streams. The first product, marketed under the name Biocube Aerobic Biofilter, was shipped in 1993. This technology was a 1993 R&D 100 Award winner.

Advanced Materials

A cost-shared CRADA funded at Argonne National Laboratory by the Energy Research Laboratory Technology Transfer (ER LTT) Program with Magneco/Metrel, Inc., a small business, has led to substantial overseas sales and the addition of about 15 new jobs at Magneco's Illinois plant. This technology involves the development of a new

pumpable, castable refractory and may ultimately decrease costs in the iron and steel industries.

Under the sponsorship of the Office of Energy Efficiency and Renewable Energy and the Office of Defense Programs, Oak Ridge National Laboratory and the Y-12 Plant have entered into a CRADA with the Coors Ceramics Company aimed at precision machining of cost-effective ceramic components.

Under the sponsorship of the Office of Defense Programs, the Los Alamos National Laboratory has entered into a CRADA with the Manufacturing Sciences Corporation and Pratt & Whitney aimed at developing more cost-effective near-net-shape processes for making beryllium components. A benefit of the new processes will be significant reduction of worker exposure to toxic, finely divided beryllium.

Under the sponsorship of the Office of Defense Programs, Sandia National Laboratories and the University of New Mexico have signed a CRADA in the area of membrane technology. This CRADA is aimed at the development and fabrication of cells for chemical reaction and separation. This technology potentially has wide application in a number of areas, including brackish or sea water desalination, fuel cells, sensors, and biomedical applications.

Under the sponsorship of the Office of Energy Research, Argonne National Laboratory has signed a CRADA with Allied-Signal aimed at learning more about the fracture and erosion properties of the advanced ceramic material silicon nitride. Silicon nitride is a leading candidate material for use in internal combustion engines, where its thermal and erosion resistance are projected to convey cost-performance benefits. Silicon nitride components could also offer cost-performance benefits in pumps as well as in oil and gas drilling tools.

Advanced Manufacturing

Under the sponsorship of the Office of Defense Programs, a CRADA between Lawrence Livermore National Laboratory and Industrial Tools, Inc., has resulted in early commercialization of an improved, high-speed cutting tool for use with hard-to-machine materials. The initial commercial application was in the manufacture of disk drives. Another potential application is the slicing of silicon wafers into chips. The biomedical and aerospace industries are considering other broad applications.

Under DP sponsorship, Sandia National Laboratories and Rocketdyne have signed a CRADA aimed at devel-

oping sensor-directed, automated manufacturing operations for Rocketdyne products.

Intermagetics General Corporation and Argonne National Laboratory are cooperating on a joint research project aimed at developing a more cost-effective process of manufacturing practical (100-yard (91-meter)) lengths of superconducting wire. The wire will be made of superconducting powders of bismuth-strontium-copper oxide provided by Argonne. Intermagetics General will extrude these powders into wire and the resultant product tests and analysis will be jointly conducted. The goal of the project is to produce wires that overcome the brittleness and capacity limitations of currently available superconducting wires.

Los Alamos National Laboratory has entered into an exclusive licensing arrangement with Quatro Corporation, a small business, for resonant ultrasound spectroscopy, a nondestructive inspection technique offering improved cost-effectiveness compared with conventional ultrasound technology. General Motors and Quatro are working together to demonstrate the full-scale application of this technique to the quality control of manufactured automobile parts, providing Los Alamos researchers with data for further improvement of the technology.

Biotechnology

New pharmaceuticals to improve cancer diagnosis and treatment are the goal of a CRADA under DP sponsorship signed by Los Alamos National Laboratory and RhoMed, Inc. Researchers at the two institutions will apply RhoMed's patented process for direct labeling of antibodies and proteins to the development of versatile copper radioisotopes. Physicians eventually could use the radioisotopes to locate and destroy tumors with radiation. The agreement combines Los Alamos' ability to produce and refine medically useful radioisotopes with RhoMed's proven expertise in radio labeling.

New products that can save money and speed drug development are being manufactured and marketed to pharmaceutical companies by Isogenetics, Inc., a private company spun off from Argonne National Laboratory. Made of algae, the products are more cost-effective isotopically labeled cell-culture media for rapidly growing the bacteria and yeasts used in pharmaceutical research to make human proteins such as growth factors, hormones, and drug receptors. The use of isotopically labeled cell-culture media permits the study of the resultant proteins via nuclear magnetic resonance spectroscopy, which detects different isotopes.

Under Office of Energy Research sponsorship, the Lawrence Berkeley Laboratory has signed a CRADA with Amgen to develop a drug for improving tendon and ligament repair. This improved therapeutic approach would offer benefits in work- and sports-related injuries. The program will combine Lawrence Berkeley Laboratory's technology for isolating Cell Density Signal-1, a critical factor for growth and collagen expression of tendon cells, with Amgen expertise in purifying large quantities of protein, sequencing proteins, and cloning and expressing genes.

High-Performance Computing

Under the sponsorship of the Office of Defense Programs and as part of the Sandia/U.S. Industry Mesh Generation Software Consortium, Sandia is conducting precompetitive generic R&D of its patented and copyrighted Mesh Generation Software and working cooperatively with Ford Motor Company, Fluid Dynamics International, Inc., MacNeal-Schwendler Corporation, and PDA Engineering to identify and promote commercial applications. The partnership intends to enhance and maintain U.S. global preeminence in the area of computer-aided engineering software development and applications for Finite Element Analysis, a powerful numerical method that solves mathematical problems in engineering and physics and which is directly applicable to more cost-effective prototype development.

Lawrence Livermore National Laboratory and six U.S. companies (IBM, Ampex, General Atomics, Maximum Strategy, Network Systems Corporation, and Zitel Corporation) have formed a consortium to address mass data storage. This 3-year project will result in integrated, commercially available computer equipment being reconfigured in new approaches to information storage and retrieval. A key technology underlying the consortium is a software data storage and retrieval system developed at Lawrence Livermore and licensed to General Atomics in 1990.

Under Office of Defense Programs sponsorship, Oak Ridge Institute for Science and Education has executed a CRADA with Interactive Presentation Systems, a small business, to combine its expertise in training and training materials with a commercial Interactive Presentation Systems interactive delivery platform. The CRADA is aimed at improving understanding of customer needs and technology capabilities for more cost-effective training in both Federal and non-Federal organizations.

TECHNOLOGY TRANSFER GOALS AND PLANS

New departmental goals for its Technology Transfer Program, as stated by the Secretary in congressional testimony on March 23, 1993, are to use federally funded research to benefit the United States and its people by stimulating and sustaining long-term economic growth and economic competitiveness, creating high-quality jobs, and protecting the environment.

Responsibilities for technology transfer will be realigned and consolidated as part of the recently announced departmental reorganization. In addition, legislation has placed additional technology transfer responsibilities upon the Department. These include the Energy Policy Act of 1992 (Public Law 102-486) and the Defense Authorization Act for 1993 (Public Law 102-484). The Department has set in place plans to implement its new responsibilities growing out of these pieces of legislation.

Total 1993 budgets to support technology transfer at departmental laboratories are \$208.8 million, as shown on page 45 of the *Department of Energy Fiscal Year 1994 Budget Highlights* and as further discussed on page 54 of that document. This does not include technology transfer activities funded as part of direct research program funds. The applied research programs—the Office of Fossil Energy, the Office of Nuclear Energy, and the Office of Environmental Restoration and Waste Management—most frequently incorporate technology transfer directly into their research programs. Other program offices, such as ER, have research programs that directly incorporate technology transfer in addition to program office budgeted line items. Steps are now under way to collect and report all funding information for all technology transfer mechanisms for a more complete picture of departmental technology transfer funding.

The Department of Energy has reconfigured its ad hoc Technology Transfer Project Group into a departmentally chartered Technology Transfer Committee consisting of top-level senior management and decision-makers. This reflects the priority of the Department's technology transfer program. This change should increase the speed and efficiency of identifying and dealing with technology transfer management and policy issues across the Department.

Further refinements in "tools" available for use by the laboratories are under way. Prominent among these is the issuance of a modular CRADA, to replace the various models (baseline and Department of Energy/Computer Systems Policy Project) now in use. The rationale for this approach is that most industry groups wishing to negoti-

ate their own model CRADAs usually focus on specific articles of the baseline model, such as product liability, U.S. competitiveness, and some or all of the articles related to intellectual property rights. The modular CRADA approach will compile individual model CRADA articles, with guidelines and criteria for their use versus other versions of the same article. The net result should be a smoothing and expediting of the now somewhat protracted process for model CRADA negotiation, allowing negotiation to focus on specific articles of interest and making the Department and its laboratories easier to work with.

Through its Office of Research and Technology Applications, each departmental laboratory is responsible for designing and implementing its own technology transfer program consistent with individual research missions. Although CRADAs are an important means of encouraging collaborative, cost-shared research between departmental laboratories and industry, they are not the only one. During fiscal year 1993, the Department's laboratories will continue to work with industry using the approach to transfer technology and know-how which is most appropriate to the situation: cost-shared contracts and subcontracts (Federal financial assistance), cooperative agreements, participation in research and development consortia, staff exchange programs with universities and industry, user facility agreements, Work for Others agreements, exclusive and nonexclusive licensing agreements, and CRADAs. The goals established by departmental laboratories for 1993 are the approval of 211 new CRADAs; the submission of 482 new U.S. patent applications; the award of 242 licenses; licensing income reaching \$2,417,000; and the formation of 8 new companies.

The Energy Research Laboratory Technology Transfer (ER LTT) Program continues to support a variety of initiatives designed to ensure that spinoff technologies with commercial potential are available from the science programs at the laboratories for industries in need of assistance in the financially risky area of precommercial R&D. Spinoff is the further enhancement and application of technology developed by a Department research program for another purpose. The projects supported by the program rely on "market pull," where further enhancements are defined by U.S. industry to meet its commercialization needs.

In 1993, the ER LTT Program will continue support for spinoff CRADAs, multilaboratory spinoff partnerships, technology maturation projects, industry-university-laboratory personnel exchanges, and small, quick-response spinoff CRADAs, particularly with small business.

The flexibility of the ER LTT Program in addressing the needs of industry is exemplified by the American Textiles Consortium partnership, a model collaboration between the national laboratories and the U.S. textile industry.

Since 1978, almost a half million U.S. textile jobs have been lost to foreign competitors who rely on low-cost foreign labor in the manufacture of finished goods. The U.S. textile industry approached the Department as an integrated industry in response to a critical-technologies workshop sponsored by the ER LTT Program. Together, the program and the industry have developed a major, multilaboratory, multi-industry participant cost-shared partnership. It addresses technology concerns of all elements of the U.S. textile industry, from fiber production to material fabrication to the manufacture and distribution of consumer goods. Key technology development areas include improved materials and processes; analysis, simulation, and computer integration; environmental quality and waste minimization; reduction of energy costs and improvement of energy efficiency; and apparel automation. A master CRADA document was negotiated and set in place in March 1993 for use under this partnership.

The Office of Environmental Restoration and Waste Management is pursuing technology transfer and industry partnerships through its Technology Development Program to maximize the use of private sector technologies in its own work and to ensure commercialization of innovative environmental technologies developed by the Department of Energy. The office has invested approximately \$4 million in 14 CRADAs with industry partners to pursue advanced bioremediation, characterization, robotics, and other environmental technologies. In addition, several innovative technology transfer models have been established to accelerate the commercialization process for advanced environmental technologies developed through departmental cleanup programs. To provide access for industry to the Department's cleanup market, the Office of Environmental Restoration and Waste Management operates a toll-free telephone service to communicate research areas to industry and to collect information on innovative technologies developed outside the Department.

The Office of Defense Programs under its Technology Transfer Initiative, funded more than 60 new projects, with a departmental cost-sharing of about \$50 million. The Office of Defense Programs also provided funding at a level of \$54 million for continuation of projects begun in previous years. Additional new projects will be funded later in 1993 from the balance of the \$141 million allocated to this activity. Projects from the most recent call for proposals are currently under evaluation.

The Defense Programs Technology Transfer Initiative now has significant dual-use cooperative research and development programs under way at its three multiprogram

laboratories and other facilities in computer applications, microelectronics, soft x-ray projection lithography, flat panel displays, manufacturing, and advanced materials.

New areas covered in the 1993 the Office of Defense Programs projects will include work on computer modeling, biotechnology, waste minimization, and a joint Department of Energy and Department of Commerce initiative for enhancing technology transfer to the U.S. machine tool industry.

The Department is engaged in ongoing management and operating contract modification negotiations with Westinghouse and with Mason & Hanger-Silas Mason, Inc., with respect to the Savannah River Laboratory and the Waste Isolation Pilot Plant (Westinghouse) and the Pantex Plant (Mason & Hanger-Silas Mason, Inc.). These negotiations would assign responsibility to support the departmental technology transfer function at these facilities. While the management and operating contractors would not be authorized to initiate CRADAs, these contractors would be able to enter into other technology-transfer-related agreements directly with industry and to participate in CRADAs negotiated by departmental laboratories with non-Federal participants.

The Department of Energy and its laboratories will continue to develop appropriate education and training programs for all staff members involved with technology transfer. The Department will develop more specialized, advanced, and tailored followup courses in addition to its technology transfer general awareness course, which has been piloted and is now undergoing final revision. The Department will develop improved tools for measuring the success of its technology transfer activities, which were a topic of discussion at the Department's Technology Transfer Process Workshop.

The only constant is change. Through all of its technology-transfer-related activities, the Department and its laboratories will enhance and continue their contributions to the economic strength of the United States in a changed and changing world and to the creation of good jobs for its citizens.

CHAPTER 15

HUMAN RESOURCES AND ADMINISTRATION

INTRODUCTION

Beginning in 1988, and continuing through 1992 under the Bush Administration, the Department of Energy focused on the conduct of operations at its nuclear facilities. The Department was organized to emphasize increased accountability and to strengthen line management responsibilities and independent direction and oversight for environment, safety, and health and for safeguards and security.

At Headquarters, then-Secretary Watkins took steps to improve program management. State and Local Assistance Program Support Offices for conservation and renewable energy were realigned to report directly to the Office of Conservation and Renewable Energy at Headquarters; the Office of Facility Transition was established under the Assistant Secretary for Environmental Restoration and Waste management to consolidate program management of facilities scheduled for eventual decontamination and decommissioning; and the Office of the Departmental Representative to the Defense Nuclear Facilities Safety Board was created to improve reporting and coordination of Defense Nuclear Facilities Safety Board recommendations affecting DOE nuclear facilities. Other major efforts included realigning the science and technology advisory functions within the Office of Energy Research to create a Science and Technology Advisor organization with a separate chain of command reporting to the Secretary; establishing a Deputy Assistant Secretary for Advanced Research and Special Technologies within Fossil Energy to integrate the oversight of crosscutting Fossil Energy advanced research efforts and to streamline project management coordination; and, with the renewed emphasis on

developing the Nation's oil, gas, and shale reserves, consolidating all gas, hydrocarbon, and oil research under one Fossil Energy Headquarters organization, the Deputy Assistant Secretary for Oil, Gas, Shale and Special Technologies. In addition, the first phase of the transfer of uranium enrichment functions from Fossil Energy to the new United States Enrichment Corporation began; the final transfer of functions to the corporation was completed July 1, 1993, when the corporation officially came into existence.

In the field, Secretary Watkins continued efforts to improve accountability, oversight, and increased efficiency. He stressed compliance with the Chief Financial Officers Act of November 1990 and established Chief Financial Officers' organizations. The Department consolidated functions within the Office of the Assistant Manager for Environmental Management and Energy Projects in the Chicago Field Office; reorganized the Fernald Environmental Management Project, which became a field office; and established the Golden Field Office to provide strengthened line management of the Office of Conservation and Renewable Energy's activities at the National Renewable Energy Laboratory and its 10 support offices.

Also in 1992, new offices were created to reflect the major geopolitical changes in the world. The Office of Arms Control and Nonproliferation was created to better focus top-level management attention on U.S. efforts to halt the spread of weapons of mass destruction, and the Office of Emergency Planning and Operations was created to improve the Department's ability to respond to emergency situations that might affect the Nation's energy supply or DOE's assets.

January 1993 signaled not only a new year, but, with a new Administration and Secretary of Energy, also a new

identity and journey for the Department. The Department embarked on a different course to achieve the new Administration's energy, environmental, and economic objectives for a changing world, and to meet Secretary O'Leary's goals and objectives for restructuring and streamlining the Department, increasing efficiency of operations, and ensuring customer-stakeholder satisfaction at all levels.

In January and March 1993, several departmental elements began to implement the Secretary's vision and objectives. The Office of Conservation and Renewable Energy changed its name to the Office of Energy Efficiency and Renewable Energy to more accurately describe its responsibilities. In the field, the Richland Operations Office strengthened the tank waste remediation program by reorganizing the Tank Waste Remediation System Project Office; improved the storage and ultimate disposal of high-level wastes at the Hanford site; and strengthened contractor oversight by moving Federal workers to areas where the work is actually performed. In addition, the Savannah River Operations Office realigned and streamlined the responsibilities of the Office of the Assistant Manager for Environmental Restoration and Waste Management between an Assistant Manager for Solid Waste, Environmental Restoration, and Technology Development (responsible for all environmental restoration, environmental management development, solid waste, and waste minimization programs) and an Assistant Manager for High Level Waste (responsible for vitrifying radioactive waste from existing tank farms, a top priority program).

In April 1993, the Secretary announced a major, mission-oriented restructuring and realignment of the Department, with the Secretary as Chief Executive Officer and the Deputy Secretary as Chief Operating Officer. The new structure emphasized establishing strategic direction and addressing broad policy issues, as well as a strong commitment to safe, environmentally sound operations through concentrated organizational alignments of field and laboratory management and environment, safety, and health oversight. The principal programmatic missions of the Department were reflected in three distinct mission teams, or "pods": Energy Programs, which reported to the Deputy Secretary, and Science and Technology and Weapons and Waste Cleanup Programs, which reported to the Under Secretary. Departmentwide, crosscutting support, independent internal oversight, and nontechnical programs reported directly to the Office of the Secretary. The restructuring

entailed numerous realignments and mergers of organizations. On June 10, 1993, with minor refinements, the Department's new structure became effective.

From July through September, departmental elements began to develop organizational and streamlining plans to implement the new organizational structures. The following Headquarters and field organizations were reorganized in 1993: the Office of Nuclear Energy; the new Office of Intelligence and National Security; the new Office of Public and Consumer Affairs; and the Albuquerque, Chicago, San Francisco, Idaho, Oak Ridge, and Savannah River Operations Offices. The new Office of the Assistant Secretary for Human Resources and Administration also merged the organizational elements of the Office of Administration and Management, the Office of the Secretary of Energy Advisory Board, and the procurement and assistance management elements of the Office of Procurement, Assistance and Program Management. This new organization established three Deputy Assistant Secretary organizations (Human Resources, Information Management, and Procurement and Assistance Management); five staff offices (Organization and Management, Executive Secretariat, Administrative Services, Quality Management, and the Secretary of Energy Advisory Board); and an Administrative and Resource Management staff.

In addition to streamlining efforts at Headquarters and in the field, a major review of the organizational structures, staffing, and operating modes of all elements of the Environmental Restoration and Waste Management Program was begun at the request of the new Assistant Secretary. This review was led by the Office of Organization and Management, with technical and professional staff participation from throughout the entire Department. The Headquarters phase of the review was completed in May 1993. The second phase, reviewing field sites, was conducted in late 1993.

On August 3, 1993, The Government Performance and Results Act of 1993 (Public Law 103-62) was signed into law. The act mandates that, as part of a staged implementation and application to all agencies, the Office of Management and Budget organize 10 pilot projects to demonstrate performance measurement. The Secretary submitted six pilot nominations to the Office of Management and Budget; but no selections were made prior to the end of the reporting period.

HUMAN RESOURCES AND ADMINISTRATION

The Mission of the Office of the Assistant Secretary for Human Resources and Administration is to guide the Department toward effective and improved management of its human and material resources and, through oversight, to ensure that this is accomplished.

Quality Management

In April 1993, the Office of Quality Management was established. The mission of the office is to assist leaders by providing the direction, professional and technical support, and resources required to implement total quality management as the method for achieving the Department's vision. The office has established the framework for the total quality management environment, which includes the foundations of leadership commitment, customer satisfaction, employee involvement, and continuous improvement. In addition, the Office of Quality Management is managing the activities related to Executive Order 12862 customer service standards and the National Performance Review and Reinventing Government initiatives.

Personnel

In 1993, the Office of Human Resources and Administration undertook workforce planning as a major departmental initiative. In addition to the streamlining required of all Government agencies, the Department is making major program shifts, away from the Cold War weapons-production environment to cleanup and energy efficiency. As a result, major emphasis is placed on accommodating reductions while providing employee retraining and recruitment in different skills areas.

The Department issued a Work Force Redeployment and Rightsizing Plan to focus attention on the actions necessary for restructuring, redeployment, and retraining of resources and rightsizing, with constant attention to the impact on employees. As part of this plan, the Department has marketed job vacancies in the growth portions of the Department through a Job Fair for Department employees and established Career Management Resource Centers to help employees with career-change and retirement issues; and it supports the Administration's proposal for voluntary separation incentive pay to improve the low attrition rates and ease retirement and career-change de-

cisions. Career Management Resource Centers have been established at two Headquarters locations to promote individual development and training at the work site, as well as to facilitate the Department's workforce restructuring and rightsizing efforts. Services include comprehensive employment and career planning information, skills enhancement, and job search programs information. These initiatives will better prepare employees for future career opportunities.

On July 23, 1993, the Secretary accepted the Defense Nuclear Facilities Safety Board Recommendations 93-3, "Improving the Technical Capability in Defense Nuclear Facilities Programs and Training and Qualifications." In so doing, the Secretary named the Assistant Secretary for Human Resources and Administration as the person responsible for overall management of the 93-3 initiatives. The Assistant Secretary assumed a leadership role immediately, and the following three near-term initiatives have been accomplished:

1. A Technical Excellence Policy statement committing the Department to upgrading the technical expertise of employees and contractors was approved by the Secretary and issued.
2. A Technical Personnel Program Coordinator position was established within the Human Resources and Administration organization, and an individual was appointed to the position. The Technical Personnel Program Coordinator is the primary point of contact for implementation of the Departmental Implementation Plan for Recommendations 93-3.
3. Numerous briefings with internal and external stakeholders were held to solicit support for implementing the initiatives.

Working with the Affirmative Employment Advisory Council, the Office of Personnel developed an Affirmative Employment Recruitment Sources Guide. This guide is an up-to-date, comprehensive resource list from which Department managers can recruit minorities, women, and persons with disabilities. Headquarters has shared this guide with the field to ensure a coordinated departmentwide recruitment strategy. The Department has continued its aggressive recruitment strategy of contacting local colleges and schools to advertise its Stay-In-School and Cooperative Education programs to students with disabilities.

The Department expanded efforts to address future needs for technical, scientific, and administrative personnel by recruiting talented college graduates and students for openings in intern, cooperative education, and other student programs. The Department entered into an agreement with

Hispanic-serving institutions and historically black colleges and universities to develop science and technology education, pairing DOE facilities with specific organizations.

In 1986, the Department began the Secretary's Summer Achievement Program to develop young talent for future technical and professional positions in the Department. The program has grown from 20 participants to almost 200 in the summer of 1992. In 1992, the program focused on high potential scientific and technical students and; for the first time, it included graduate students—in spite of the Department's ongoing efforts at rightsizing. During the summer of 1993, the program remained active, involving 153 students from diverse ethnic and academic backgrounds. In addition, the Department selected a number of students for cooperative education positions, and for consideration for future career internships upon graduation.

Employee Safety and Health

The Department took active measures in 1993 to ensure the safety and health of Headquarters employees, including participation in an indoor work environment study with the General Services Administration and two other Federal agencies at the DOE Germantown facility. Also, in 1992, the Department implemented a safety and health plan for Headquarters that identified and corrected the following several health and safety problems: installing automatic operating entry doors, making restrooms more accessible for persons with disabilities, rebalancing major air handlers to improve indoor air quality, and retrofitting five elevator cabs with a new dispatching system. Further, asbestos-containing materials found during renovations were removed, and asbestos-containing materials in the Germantown mechanical equipment rooms continued to be removed.

Headquarters Energy Conservation

On February 16, 1993, a contract was awarded to renovate the lighting resources at DOE Headquarters. Under this project, completed on September 30, 1993, the contractor retrofitted 36,832 existing lighting fixtures with energy-efficient electronic components, which reduced lighting electricity by 62 percent and produced actual annual savings of \$399,057. The Office of Administrative Services initiated the project using a Shared Energy Savings system contract negotiated competitively under the

provisions of Public Law 99-272, the Comprehensive Omnibus Budget Reconciliation Act of 1985. The success of the project has set a standard in lighting efficiency in the Federal sector.

Training and Development

In 1993, Human Resources increased its emphasis on scientific and technical training to the Department's Federal scientific and engineering staff. The office provided assistance in curriculum and course development for technical training programs affecting all departmental programs. The Professional Skills Training Program has made major revisions to program management, project management, and procurement and assistance curricula, incorporating state-of-the-art training techniques and expanding the curricula to include major departmental initiatives and to reflect policy changes.

The office also revised certain supervisory and management training programs to emphasize the skills required to ensure increased accountability, promote a culturally diverse workplace, respond to dramatic changes in departmental programmatic priorities, and to allocate limited resources. In addition, the fifth Senior Executive Service Candidate Development Program began. Human Resources established a working group to provide guidance to and coordination with a number of the Department's intern programs.

Technical Training Programs

The office continued to develop an expanded curriculum of technical training. Twelve separate courses on principles of engineering science for the Department's Federal technical employees were offered for the first time.

In addition, staff from the Office of Professional and Technical Training and Development conducted a series of site visits at DOE nuclear/technical field sites, followed by Technical Training Excellence Workshops. Workshop participants developed the substantive elements of departmental programs and standards for establishing a systematic approach to training, qualifications, and testing programs; policies regarding departmental training infrastructure, career systems, and intern programs; and a centrally managed technical curriculum for the Department's technical employees. The Office of Human Resources and Administration will issue the departmental guidance establishing and implementing these policies and programs in 1994.

Energy Technical Training Center

In 1993, Albuquerque, New Mexico, was selected as the site for the Energy Technical Training Center. Processes for funding and renovating the center are under way; it should open in the fall of 1994.

The approved concept and curriculum for the center will be revised to reflect the changing mission and priorities of the Department. The Department expects to collaborate with instructional design professionals from academia, industry, and other government agencies in presenting programs at the center. The training center will provide a focal point for technical training for the Department's scientific, engineering, and technical staff.

Supervisory and Management Training Program

The Supervisory and Management Training Program responds to new organizational initiatives and the overall development needs of the Department's supervisors and managers. The program includes individual courses that are mandatory for new supervisors, advanced and refresher courses for experienced supervisors and managers, and development programs for potential supervisors and managers. Advanced courses focus on critical public policy issues and responsibilities, such as managing diverse work groups, strategic planning, and drug-free workplace responsibilities. All of the supervisory and management programs support the Department's strategic planning, total quality management, and diversity initiatives.

Senior Executive Service Candidate Development Program

The purpose of the Senior Executive Service Candidate Development Program is to help the Department meet its needs for future executives and to comply with the provisions of the Civil Service Reform Act requiring Federal agencies to implement programs to systematically develop Senior Executive Service candidates. Graduates are not guaranteed Senior Executive Service positions, but approximately 70 percent of the previous graduates have entered the Senior Executive Service. In 1993, the Department selected 43 participants from approximately 700 applicants, for its fifth Senior Executive Service Candidate Program. Because women and minorities are underrepresented in the Senior Executive Service, both Governmentwide and in the Department of Energy, applicants from these groups were intensively recruited. As a result, the Department was able to attract an applicant

pool with three times the percentage of women and minorities as past applicant pools. The class selected for 1993 included 32.6 percent females and 37.2 percent minorities. Of these, 4.7 percent are minority females. In addition, 7 percent of the candidate class are persons with disabilities.

Professional Skills Training Program

The Department has substantially improved its program management, project management, and procurement and assistance management curricula. These improvements include adding the latest departmental guidance on strategic planning and multiyear program plans as they relate to program and project management activities. Curricula are continually updated to ensure that the most current policies are being taught. For example, the professional skills curriculum was expanded in 1992 to include the areas of environment, safety, and health, quality assurance and quality improvement, and financial management; and the value engineering curriculum was enriched in 1993 by special seminars addressing the state-of-the-art in these functions, new legislation, and policy directives that directly impact job performance.

Career Management/Development Program

The Career Management/Development Program, initiated in 1993, is designed to introduce a variety of career management and planning tools to organizations, supervisors, and employees throughout the Department and measurably raise the level and quality of these activities. The program includes workshops to help employees manage their careers and personal growth; the creation and maintenance of individual development plans for both employee and supervisor; assistance to help employees succeed in their chosen careers; and a consistent, departmentwide employee orientation program.

Training Technology and Workforce Planning

The Department is placing significant emphasis on using advanced technology to improve the effectiveness of training delivery and to reduce costs. For example, the use of satellite broadcasts to make technical training courses available to departmental offices nationwide was expanded in 1993. Additionally, in 1993, Human Resources established Learning Resource Centers in the Forrestal and Germantown facilities. The centers, which opened in October 1993, promote individual development and training

at the work site and use state-of-the-art multimedia technologies.

Policy and Evaluation Program

The major functions of the Policy and Evaluation Program are to assess departmental training needs, establish policy and issue guidance for the development and implementation of training programs to ensure that the Department's facilities are managed and operated by a technically proficient staff, and to review and evaluate departmental training program initiatives to ensure their consistency with Department policies and needs. A major revision of Departmental Order 3410 was being completed; this revision will include comprehensive guidance on topics identified through departmental survey as critical to meeting changing missions and directions. In addition, a Directory of Work Activities, which includes knowledge and skills pertinent to job performance throughout the departmental community and the training necessary to meet those requirements, was developed.

Information Resources Management

In October 1992, the Department updated and reissued its Strategic Plan for Information Resources Management. The plan focuses on managing the information required to support departmental programs, rather than just on the technology resources that process this information. The plan more closely links information resources management strategic goals and missions with departmental strategic goals. In recognition of the importance of information to meet the Department's critical success factors, the position of Deputy Assistant Secretary for Information Management was created.

Because the management of information resources (including records) is a critical element of program planning and execution, senior management support is vital to its success. To solidify such support, the Department established the Information Resources Management Council, composed of representatives of program and field elements. This council fosters a high level of cooperation in supporting departmental priorities and program requirements. To specifically address the management of records, the Department established a Records Management Committee, composed of representatives from the field and

Headquarters offices. The Department initiated a strategic planning process for the development of an accepted, departmentwide standard operating guideline for electronic document format and exchange.

In 1992, the Department undertook a major initiative to develop records management plans. These plans will help the Department correct the records management deficiencies identified in a National Archives and Records Administration evaluation. The corrections were recommended by the General Accounting Office. The phase I (1993–1994) plan focuses on developing and implementing the program to provide for the disposal or transfer to the National Archives of records no longer needed by the Department. This supplements a 1991 initiative to inventory and describe all records held by the Department and its contractors.

In 1993, the Office of Information Technology Services and Operations completed a project for the Office of the Secretary of Energy to provide electronic mail and file transfer capabilities to the Office of the Secretary, Headquarters principals, and field management. The project, implemented in three distinct phases, provided the Office of the Secretary and Executive Secretariat staff with cc:Mail and local area network interconnectivity, extended the network to include all Headquarters first-tier principals, and then interconnected separate electronic mail systems at 10 operations offices and 6 national laboratories to Headquarters, thereby allowing managers and directors of those facilities to transfer files electronically to Headquarters and vice-versa. This departmentwide capability will help conduct of departmental business at the senior level. In 1994, efforts will concentrate on expanding this capability to all Federal and contractor employees at these locations and interconnecting additional departmental facilities to establish departmentwide interoperable electronic mail and file transfers, as envisioned by the Government Open System Interconnection Profile policy statement issued in August 1990.

The Department also continued to aggressively structure its facilities to meet national security and emergency preparedness telecommunication needs. These activities include upgrading emergency operations centers departmentwide. The 7,000-square-foot (650-square-meter) Headquarters Emergency Operations Center, which opened in December 1992, features state-of-the-art computer, video, and telecommunications systems that can operate in both classified and unclassified modes. Additionally, technicians installed FTS 2000 (Federal Telecommunications System) compressed video transmission service in the Department's common-user video facilities. This service allows up to 14 users to simultaneously tele-

conference in an unsecure mode; includes Department field locations that are not in the Department secure video network; and can be used to conference other Federal agencies and commercial video networks that have compressed video transmission service.

The Department's use and effectiveness of broadcast video was also expanded. The Secretary's meetings were broadcast via satellite to Headquarters and field sites on several occasions, as was the Vice President's town meeting. Other 1993 activities included establishing diverse paths for telecommunications circuits to and from departmental facilities, installing secure telephone units, obtaining priority restoration assignments for the Department's critical telecommunications services, seeking mutual aid agreements with State and local governments, and exploring emerging telecommunications technologies. These activities are closely correlated with the national level policies and programs of the National Communications System to ensure that the Department's telecommunications facilities are, and remain, a vital part of the overall Federal system.

Reflecting its responsibilities to protect national security interests, the secure automated message processor was installed departmentwide to receive, analyze, and disseminate message traffic supporting mission-critical needs of the Department's intelligence community. The Department continued to conduct communications security (CONSEC) audits and emission security (TEMPEST) inspections to ensure compliance with national policy; and it conducts computer security assurance reviews to evaluate the unclassified computer security program at departmental sites. The Computer Incident Advisory Capability, a team of computer scientists from Lawrence Livermore National Laboratory, helps the Department respond to computer security incidents in departmental and other Federal departments and agencies.

In 1992, DOE participated in a broad-based Department of Commerce investigation to determine future U.S. requirements for use of the radio frequency spectrum, including technology trends that would affect its use well into the 21st century. As part of this investigation, the Department identified all projected departmental spectrum-dependent information technology needs through the next decade.

Directives System

In March 1992, DOE formed a departmentwide project team to recommend improvements to the Departmental Directives System. The Secretary approved the specifica-

tions for a new system in December 1992, which establishes a series of management improvements to assist in the development and implementation of internal policy and procedures. Improvements to the system include advance notification and early involvement in the development process by those organizations with technical knowledge and implementation responsibilities; identification and evaluation of resource implications of the directive; and the establishment of the Directives Control Board, which is composed of senior management responsible for system oversight and issue resolution. The board held its first meeting in March 1993.

In May 1993, the Implementation Plan for the new Departmental Directives System was approved by the Directives Control Board. Beginning in August, training sessions were conducted to familiarize system users with the new system procedures. Of particular interest, a Departmental Directives Workshop with field and contractor personnel was held in Albuquerque, New Mexico, in October to communicate the new directives system. The system was officially implemented in September 1993, and three pilot orders were reviewed to test concepts of the new system. These reviews documented both volume reduction and cost savings of more than \$30 million per year; the orders are anticipated to be issued in the first quarter of calendar year 1994.

The new directives system will be instrumental in meeting the objective of reducing internal regulations in support of the new departmental and National Performance Review initiatives.

Support Services Contract Management

Following the cost comparison principles set forth in Office of Management and Budget Circular A-76, "Performance of Commercial Activities," the Department revised its policy for management of support services contracts (effective October 1, 1992) to include a requirement to conduct a cost-comparison analysis of in-house versus contract operations to determine the most economical mode of operation. Human Resources authorized approximately 150 support services contracts in 1992, and approximately 140 support service contracts in 1993.

The Secretary established a Contract Reform Task Force in June 1993 to review the Department's contracting mechanisms, including the use of support services contracts. A Support Services Task Team formed under this group developed recommendations for improving the use of support services (10 percent reduction in 1994, increased use of performance-based contracts, and improved

training of those personnel overseeing the contracts). These recommendations will be reviewed before their implementation.

Human Resource Automated Systems

The Department is improving its payroll and personnel human resource systems. The Energy Time and Attendance System, which will automate the existing manual process, has been developed and implemented on a pilot scale. This system will reduce paper flow and allow time and attendance data to be transmitted electronically. Annual tangible savings of \$135,000 are anticipated, which will pay back the development costs in less than 3 years. The pilot system has successfully operated 277 timekeeping units with 2,400 employees. Phased implementation began in July 1993 for the remainder of the Department.

WORKFORCE ANALYSIS AND PLANNING

During 1993, Human Resources moved quickly to plan for the implementation of the recommendations of the National Performance Review and the President's call for Executive Branch agencies to streamline their organizations and operations. Human Resources has instituted a workforce analysis and planning effort to address departmental human resource concerns. Using the Strategic Planning Process as a foundation, efforts have focused on integrating the human resource initiatives currently under way with the planning and future direction of additional projects. These efforts are an integral part of the overall departmental workforce restructuring and streamlining. Included are several individual 1993 initiatives that respond to specific Presidential or Office of Management and Budget guidelines. These include the Department's plan to reduce the number of subunits and organization levels and the related number of management-supervisory positions (Senior Executive Service and GS/GM 14–15 positions) and to increase the ratio of employees to supervisors.

A Workforce Redeployment and Rightsizing Plan has been proposed to provide guidance for redeploying departmental staff from lower priority to higher priority programs, a plan for training-retraining of departmental employees, and an outplacement program to help move employees from areas of surplus staffing to areas requiring additional resources. These efforts will help develop a full-time-equivalent staffing allocation profile for the

Department for fiscal years 1994–1999 that reflects the optimum staffing within budgetary constraints.

Work for Others

The Department performs fully reimbursable work for other Federal and non-Federal entities that amounts to approximately \$1.7 billion annually. The level of overall work has decreased during the past several years because of reductions in defense-related activities, which represent more than 75 percent of this work. The Department instituted a plan for conducting management reviews of all departmental field offices to ensure that Work for Others policies and procedures are properly implemented and that Work for Others makes the most effective use of the Department's national laboratories and facilities. On-site management reviews had been completed at seven operations offices as of September 1993 (the last operations office review was scheduled to be completed during October 1993). The Operations Offices were found to be in general compliance with the policy and procedures contained in the departmental Work for Others order. Some shortfalls were found in the areas of file documentation and insufficient detail on subcontracting. Followup action to ensure that the recommendations have been implemented is scheduled for 1994.

In July 1993, a Process Improvement Team was formed to streamline the overall Work for Others process. A revised departmental order to reflect these improvements (parallel reviews, graded approach for approval, minimal Headquarters involvement, and so forth) was scheduled to be issued in early 1994.

PROCUREMENT, ASSISTANCE, AND PROGRAM MANAGEMENT

The Office of Procurement, Assistance and Program Management (PR) formulates policy, implements procedures, and reviews and oversees activity for DOE and its contractors in the areas of procurement, financial assistance, and program and project management and control. It is responsible for ensuring that DOE adheres to procedural and statutory requirements in the acquisition of goods and services; performing reviews of DOE contractor procurement activities to ensure strict compliance with statutory, regulatory, health and safety, and operational procedures in all facets of operations; and ensuring that day-to-day

operational activities and initiatives by DOE contracting offices conform to requirements set forth in Secretary of Energy notices and further the goals and objectives of the Energy Policy Act of 1992.

Competition in Contracting

The 1992 annual report to the procurement executive, as required by the Competition in Contracting Act of 1984 (Public Law 98-369), confirmed that, similar to previous years, approximately 90 percent of DOE's new contract awards were competitive.

Management Initiatives

In 1992, the office continued its efforts to further improve contract, business, and project management practices and to establish greater contractor accountability. The work authorization and control process developed in 1991 was incorporated into the major production contracts under which the Department's Government owned-contractor operated plants and test facilities are operated. This process will enforce more effective fiscal accountability on both the DOE management team and the contractor personnel and will provide a better basis for matching award fee determinations to the work to be done under the contract.

On June 18, 1993, a Departmentwide Contract Reform Team chaired by the Deputy Secretary was established to review the Department's contracting mechanisms and practices. Among other things, the team will focus on contract design; contractor performance measurement; competition; reliance on, and reduction in the use of, support services contractors; contractor indemnification; and contractor oversight.

Project control system guidelines were revised for large-dollar construction activities to reflect commercial practices and to emphasize controls in high-risk areas; the goal is to maximize control at the lowest cost to the Govern-

ment. PR improved management systems used by departmental managers and contractors to plan, budget, and control activities to provide more complete and timely information. In addition, PR developed a new project cost and schedule reporting system that encompasses all significant project information and presents it in a concise form useful to management.

To better align the program-project management and control functions with the Department's field structure, which has program execution responsibilities, program-project management and control responsibilities were transferred in late 1993 from PR to the newly established Office of the Associate Deputy Secretary for Field Management.

Contractor Drug-Free Workplace Program

In 1992, PR began implementation of a drug-free-workplace program at DOE facilities operated by its management and operating contractors.

Motor Vehicle Management

The Department's motor vehicle fleet consists of 20,613 vehicles, of which 13,658 are DOE-owned and 6,955 are leased from the General Services Administration. To reduce the consumption of petroleum fuels, the Department continued to meet the requirements of Executive Order 12759, "Federal Energy Management," by implementing a 10-percent fuel reduction program along with a 5-year acquisition plan for alternative-fuel vehicles, both to be accomplished by 1995. The Department also completed cost reduction actions required under Subtitle C—Federal Motor Vehicle Expenditure Control, Public Law 99-272. DOE's vehicle expenditures for motor vehicle operations in 1992 totaled \$79.5 million, a 7.6-percent increase from 1991. This increase was due to expanded departmental transportation requirements.

CHAPTER 16

FINANCIAL OPERATIONS

INTRODUCTION

The Office of Chief Financial Officer (CR) oversees all financial management activities relating to the Department of Energy's programs and operations, including management of the Department's budget formulation and execution processes and development and maintenance of the Department's integrated accounting and financial management system, including financial reporting and internal controls.

During 1992 and 1993, initiatives by the Department and CR to further strengthen financial management led to significant improvements in financial operations in several areas. Specifically, CR has accomplished the following:

1. For the first time, a strategic plan was developed to guide activities within the financial function. As part of this, CR adopted a vision of becoming "World Class" in financial management. The financial management staff was trained in total quality management, and process improvements were initiated in the areas of financial stewardship, full partnership, customer orientation, human resources management, and technology/information architecture. Customer surveys were conducted in 1993 to identify areas for improvement.
2. In continued response to the Chief Financial Officer (CFO) Act and Secretarial initiatives, several important steps were taken to improve Department financial management. These involved improvements to the organizational structure and enhancements to reporting relationships:

- In 1992, for 9 of the 10 major field finance offices, the Department completed implementation of a more uniform field organization structure that defined field CFO offices, including upgrading of field CFOs to Senior Executive Service status. This helps to assure more consistent, better quality financial support, particularly regarding oversight of management and operating contractors. Key concepts of this were adopted by the remaining 14 field financial offices.
 - In late 1991, a working group led by the Acting CFO developed and published the final procedures and documents to implement the personnel aspects of the Chief Financial Officer Act. Standard personnel documents, including position descriptions, uniform qualification standards, and performance standards, were published for the 10 major offices in December 1991, and were implemented for virtually all field office personnel in 1992. This served to strengthen the Department's field financial management activities.
3. The CFO established a standing Budget Advisory Committee, and the Department and the CFO instituted a Quality Planning-Based Budget Process. This provided for enhancing the preparation of the annual DOE budget by providing for a more consensus-based process and better focus on customer needs. Performance measures were developed for all DOE programs and included in the 1995 budget request to Congress, far ahead of the 1999 date mandated by the Government Performance and Results Act.

4. The CFO has devoted significant attention to improvement in contractor and DOE financial systems. The Financial Management Systems Improvement Council, formed in 1993, began working to achieve the benefits projected from sharing of best practices and systems among the Department's management and operating contractors. During 1993, the networking requirements data base design and systems specifications were completed for a replacement to the Department's Financial Information System.
5. During 1992 and 1993, CR made significant progress in improving the management of overhead budgets, including reviewing costs and issuing targets to individual programs for use in the 1994 Office of Management and Budget (OMB) budget and establishing the Overhead Initiatives Working Group (now called the Budget Advisory Committee), which implemented a process for systematic review and approval of overhead.
6. CR has undertaken a major initiative to reduce the level of uncoded balances within the Department. This includes development in 1992 of a new system for reporting and analyzing uncoded balances and actions taken to apply uncoded balances to help finance the Department's programs in 1994 and 1995.
7. CR has taken steps to strengthen the resolution of financial management policy issues, including establishment in 1992 of a Financial Policy Advisory Board to help identify and resolve sensitive and complex issues.
8. Significant improvements were made in cash management regarding travel, debt collection, on-time payments, and accounts receivable reporting.
9. The Department and CR have made several significant accomplishments regarding audit resolution, compliance reviews, and enhancements to management control:
 - DOE pursued a rigorous program regarding response and follow up to Inspector General (IG) reports. The program stresses the involvement of senior line management in addressing any IG or General Accounting Office (GAO) findings.
 - The Department performed compliance reviews on an accelerated schedule that concentrated on evaluation of contractor financial systems and controls and field operation oversight of contractor financial operations.

— As required by the Federal Managers' Financial Integrity Act, DOE identified and developed a corrective action plan for each of 14 material weaknesses related to management controls and financial systems. In addition, the CFO established a process improvement quality team to enhance customer satisfaction.

10. The CFO incorporated several improvements, including expanded overview and performance measures, into the audited financial statements that were published.
11. A comprehensive Financial Management Development Program was instituted in 1992 to provide training at all career levels. This program is designed to ensure a cadre of well-qualified candidates to fill critical financial management positions. The training involves both classroom and self-study courses and provides detailed curriculum tailored to specific areas, such as accounting or budgeting.

The CFO has already begun to realize sizeable benefits from the initiatives that have been undertaken. The following is a small sample of the improvements that have been made or identified:

1. The financial management staff conducted an "idea day" during which over 700 ideas for improvement in financial management were developed. Many of these have already been adopted.
2. A customer survey was conducted that identified 117 areas where our customers felt improvements could be made. These have been categorized and assigned for action.
3. A process improvement team developed recommendations to reduce the processing time of a travel voucher from 40 days to 3 or fewer.
4. Cash management efforts have led to estimated savings of over \$40 million in 1993.

Other specific accomplishments are discussed below.

STRATEGIC PLANNING PROCESS

During the fall of 1993, CR began a concerted effort to plan for the future and to improve the quality of its products and its customer service. To provide a framework for improving the Department's financial management community to be the "best in class" by the year 2010, the CFO

instituted a strategic planning process. Late last year, CFO management, customers, and stakeholders met in planning sessions to develop the Department's first Financial Management Strategic Plan. By March 1994, the initial plan was completed and widely distributed. The Plan fully supports the Management Practices Critical Success Factor outlined in the Department's Strategic Plan. It is a good beginning, but it is only a starting point, and the financial management community is looking forward to future iterations.

The plan is premised on a comprehensive vision that begins:

The Department of Energy is a leader in the field of financial management and is ranked among the best in government and industry.

The vision then unfolds into five interrelated major thrust areas:

1. Financial Stewardship, which focuses on the responsibility of managing the Department's financial resources ethically and with integrity.
2. Full Partnership, which emphasizes a culture of cooperation and support between financial managers and program officials.
3. Customer Orientation, which focuses on developing a recognition of customer needs, requirements, and expectations for financial management products and services.
4. Human Resources Management, which emphasizes the creation of a highly skilled, motivated, empowered, and diverse workforce.
5. Technology/Information Architecture, which recognizes the need to place the appropriate priority on financial management information structure and automated systems. The success of this crosscutting thrust is instrumental in the accomplishment of the other strategic thrust areas.

The major thrusts are supported by one or more goals, objectives, and strategies, and they have become an umbrella for all CFO initiatives, including those resulting from the Contract Reform efforts and other quality activities.

When the Plan was presented to the Secretary, she expressed strong support for the efforts in it. She also asked that a number of activities embedded in the Financial Stewardship, Full Partnership, and Technology/Information Architecture strategic thrust areas be completed much earlier than originally envisioned. These major undertakings are under way, and process improvement teams staffed

by stakeholders within the Department have been formed and are working toward goals set by the Secretary.

In support of the planning process, the CFO also conducted customer surveys during 1993 that focused on customer service and attempted to identify areas where the financial management community, as well as CR, could improve. The surveys, conducted at two levels in the Department, resulted in a response rate of more than 70 percent and produced many useful suggestions for improvement. The customer response has been linked to the strategic plan, and the priority recommendations are being incorporated into the improvement efforts.

FINANCIAL MANAGEMENT

Introduction

The CFO Act and selected Secretarial initiatives had considerable impacts on the Office of Chief Financial Officer in 1992, resulting in a larger role for the Departmental CFO in the management and oversight of DOE operations.

Financial Management Organizational Structure

DOE's field finance offices had traditionally developed organizational structures unique to their local environments. In some areas, this tradition contributed to uneven levels of performance, particularly in the performance of oversight of management and operating contractors. Therefore, the Acting CFO determined that the 10 major field finance offices would benefit from a more uniform organizational structure to ensure effective operations; in June 1991, the Acting CFO published a proposed organizational structure for these field finance offices. This structure defined 10 field office CFOs, each supported by 3 suborganizations, for accounting, budget, and financial review. This reorganization proposal did not include the 14 remaining field finance offices, most of which were small, few of which had oversight responsibilities for integrated management and operating contractors, and some of which were dedicated to power marketing activities; however, each of these offices was encouraged to adopt those portions of the standard CFO organization that would improve its effectiveness.

Of the 10 major field offices, all but 1 completed their reorganizations in 1992; the remaining office is in the process of obtaining final approval for reorganization and has developed and implemented interim changes that satisfy the intent of the proposed reorganization. In addition, a number of the other field finance offices have incorporated some of the key concepts of the standard organizational structure.

Reporting Relationships

To respond to the requirements of the CFO Act and to Secretarial initiatives, changes were necessary to provide the Acting CFO with increased control and authority over the financial management functions in the field finance organizations. Before passage of the CFO Act, the DOE Controller had an informal, dotted-line relationship with the field CFOs. The exact authority of the Controller and the Controller's relationship to these offices were not clearly or concisely described in any single departmental order. However, a working relationship had evolved through the years that was reasonably effective.

To improve financial management, the Secretary established a formal, dual-reporting relationship in Secretary of Energy Notice 34-91 (SEN-34-91), "Implementation of the Chief Financial Officers Act of 1990 (P.L. 101-576)," whereby the CFOs at the 10 major field offices reported directly to the Departmental CFO, as well as to their local field office manager, on all financial management matters. The existing dotted-line approach remained for the other offices. This relationship was implemented at the end of 1991 and strengthened the financial management of the Department in 1992.

In addition to strengthening the Departmental CFO's authority in organizational and reporting relationships, the CFO was also given responsibility for approving all key financial management personnel actions, including the selection of field CFOs, approval of position descriptions and qualification standards, and input to annual performance appraisals, proposed awards, and disciplinary actions.

In late 1991, the Acting CFO formed a working group to develop and publish standard position descriptions for the four key financial management positions (field CFOs and heads of accounting, budget, and financial review), uniform qualification standards (knowledge, skills, and abilities), ranking factors for recruitment actions, and performance standards. DOE published these personnel docu-

ments for implementation at the 10 major field offices on December 20, 1991. On January 30, 1992, the Acting CFO published the same documents and procedures relating to the remaining field offices, directing them to use them if they were appropriate for their mission and operation. The standard personnel documents were implemented for virtually all affected field office personnel in 1992.

QUALITY PLANNING-BASED BUDGET PROCESS

To address budget issues and to continue ongoing efforts to improve DOE's budget process, the CFO established a standing budget advisory committee. This committee is chaired by the Office of Budget, and membership consists of a cross section of program, field, and contractor representatives. Subcommittees have been formed to assess specific issues and develop action recommendations for the CFO. The Department is continuing to conduct budget validation reviews to improve confidence in and the quality of budget estimates.

The Department has adopted a new Quality Planning-Based Budget Review Process that allows the major program elements of the Department to reach consensus on key budget formulation issues. This new quality process focuses on aligning the Department's budget with strategic plan goals and objectives, resolving issues that cross-cut organizational lines, and making related tradeoff funding decisions consistent with departmental priorities. The Department's quality budget process team members meet as needed throughout the budget formulation process. The new process focuses on fully satisfying customer expectations, and external stakeholders are invited to actively participate. In its initial year of operation, the new quality budget process team successfully reached a consensual budget position on numerous difficult and cross-cutting budget issues.

To address other improvements in DOE's budget process, the CFO supports a standing budget stakeholders group. This group is chaired by the Office of Budget, and its membership includes a cross section of program, field, and contractor representatives. Groups have been formed to assess specific issues and develop action recommendations for the CFO. In addition, the CFO is continuing to conduct customer surveys and solicit suggestions from budget process participants on how to improve the process.

FINANCIAL MANAGEMENT SYSTEMS IMPROVEMENT

System Improvements in Integrated Management and Operating Contractor Financial Management Systems

The Department relies heavily on integrated management and operating contractors, which maintain separate sets of accounts and records for recording all business transactions in accordance with departmental accounting practices and procedures. Each integrated contractor has a separate and unique financial management system, and there is little commonality among the contractors except for their ability to report by the Department's requirements.

In FY 1993, the CFO chartered the Financial Management Systems Improvement Council to explore ways to improve financial management for the Department's contractors. The council is composed of 10 members from integrated management and operating contractors, 2 operations office representatives, and 4 permanent members representing the CFO. The council's vision statement captures the fundamental intent of its activity:

Improve contractor financial management system processes which will result in increased efficiency and effectiveness through: (a) the sharing of successful approaches (best business practices) and benchmarking among contractors, (b) the development of business requirements and common technology for financial management systems, and (c) the identification of systems which lend themselves to common processes in pursuit of standardization.

Although many activities of the council are considered longer term initiatives, the first year has produced significant short-term results, as well as notable progress toward the longer term objective of departmentwide commonality of financial systems and processes. Representative accomplishments to date include the following:

1. Completion of industrywide benchmarking studies, which has resulted in notable process efficiencies at six contractor locations.

2. Completion of "best practices" and systems inventory data bases, two onsite systems demonstrations, and numerous exchange visits resulting in the transfer of existing systems architecture and/or design and specification requirements to 15 contractor locations. Transfer of this capability has resulted in contractor cost reductions/avoidance.
3. Completion of cost accounting charging practices study, standardization of indirect cost terminology, and a cost accounting information primer has resulted in improved industry communication, which will result in commonality of data submissions and improved comparability.

Longer term initiatives in progress that will further the council's objectives include the following:

1. Development of functional and operational requirements (F&ORs) for financial systems design. Four separate accounting-related F&ORs are under development at this time. Completion of these requirements documents will allow the development of standard industry-accepted accounting system components.
2. Establishment of a systems clearinghouse service to ensure contractors take full advantage of existing systems, on an industrywide basis, prior to developing and implementing new and individual solutions.
3. Development of an indirect cost determination handbook that will provide an industrywide guideline for indirect cost classification and analysis.

As initiatives and activities are completed, the council will continue to develop new strategies and approaches using an industry-cooperative forum to leverage experience and expertise, thereby creating synergistic, cost-effective solutions and improvements in the Department's financial operations.

DOE developed and completed functional user requirements and technical assessment documents to determine the most cost-effective approach to redesigning or enhancing the Department's Financial Information System, which the Department uses to edit, consolidate, and report its financial activity to central agencies and internal management. DOE decided to replace the Financial Information System with a new system, the Management Analysis and Reporting System. During 1993, the networking requirements data base design and detailed systems specifications were completed. The new system will take advantage of

the newest technology and provide better reporting capabilities; it will become a module of the Departmental Integrated Standardized Core Accounting System. This system integration is in line with the Department's strategy to consolidate and standardize financial management systems wherever possible to eliminate the cost of duplication and redundancy. DOE has established a Departmental Integrated Standardized Core Accounting site within the Departmental Accounting and Analysis Division, which is phase 1 of the four-phase project; the follow-on phases include conversion to a new data structure, implementation of the U.S. Government Standard General Ledger at the transaction level, and other central reporting capabilities.

DOE achieved additional progress in system standardization in 1992, when the Alaska Power Administration began using the Southwestern Power Administration's financial management system through remote online access. During 1993, the Power Marketing Administration Advisory Group prepared an implementation plan to consolidate the financial management systems of the Alaska, Southeastern, and Southwestern Power Administrations with the Western Area Power Administration's system. The consolidation should be completed in 1996.

DOE completed the functional requirements and programming for the new automated Energy Time and Attendance System. Pilot testing of the system began in January 1993, and a multiphased, departmentwide implementation was initiated in July. This improvement will result in a significant savings of time and will enable more accurate recordkeeping. The system is scheduled to be completely implemented by the end of 1994.

OVERHEAD COSTS

In 1991, the CFO initiated a concerted effort to improve the management and oversight of management and operating contractors' overhead costs. The Office of Budget made sufficient progress in reviewing overhead costs during the summer of 1992 to permit the issuance of overhead targets to individual programs for the 1994 Office of Management and Budget (OMB) budget. In addition, an Overhead Initiatives Working Group with representation from Headquarters programs, operations offices, contractors, and the Office of Budget was established to develop a process for the systematic review and approval of overhead in the DOE complex. This process, which was promulgated in the 1995 unified field budget call issued in January 1993, consists of an annual overhead re-

view and approval process for the execution year and budget year (conducted by the operations offices in consultation with the CFO and Headquarters program offices), review by the CFO of annual reports on allocable costs submitted by the operations offices, a more indepth review of the various components of overhead carried out by the operations offices on a 5-year cycle, and a monthly execution review by the operations offices to compare actual against projected overhead, with significant variances reported in the biweekly report to the Departmental CFO. The value of the Overhead Initiatives Working Group's shared approach to the overhead management issue was clearly demonstrated, and its purview has been expanded to include other budget issues. As a result, its name has been changed to the Budget Advisory Committee to reflect its more universal responsibilities. In addition to overhead, the committee initially will focus on improving budget formulation, enhancing management of uncosted obligations, and developing performance measures. Creation of the committee has institutionalized a mechanism for continuous financial management improvement that is representative of the stakeholders.

UNCOSTED BALANCES

In 1992, the Office of Chief Financial Officer instituted a new system for reporting and analyzing the status of uncosted funds obligated by DOE to contracts with its integrated contractors for management and operation of the Department's Government-owned, contractor-operated national laboratories and other selected facilities. This system requires a report from each integrated contractor that categorizes the uncosted contract balances by contractor encumbrances, scope of work approved by DOE program managers but not yet encumbered by the contractor, contract prefinancing, and undesignated funds. The yearend analysis of these data becomes the basis of a report to Congress in compliance with Public Law 102-486, which requires that DOE submit a report along with its annual congressional budget request explaining the impact of the review of the Department's uncosted balances on the budget being simultaneously submitted.

In financing the Department's 1995 budget and implementing congressional actions on fiscal year 1994, the Department plans to use \$963.4 million of fiscal year 1993 uncosted balances. Of this amount, \$344.6 million is being used in fiscal year 1994 in compliance with congressional appropriations action, and DOE proposes to use \$618.8 million in support of the Department's fiscal year

1995 congressional budget request. In addition, \$1,360.0 million of unobligated balances is being applied to meet congressional requirements in fiscal year 1994. Most of these unobligated balances represent uncosted balances at the end of fiscal year 1992, which were later deobligated or otherwise reserved in anticipation of congressional offset requirements. In total, \$2,323.4 million of prior-year balances, both unobligated and obligated but uncosted, are being applied to finance the Department's programs in fiscal years 1994 and 1995. The Department believes that the application of these large balances, together with aggressive efforts by program managers at Headquarters and in the field to ensure proper management of funds, should lead to even lower uncosted balances at DOE management and operating contractors at the end of fiscal year 1994.

FINANCIAL POLICY

In February 1992, the Acting CFO signed a charter formally establishing the Department of Energy Financial Policy Advisory Board to help identify and resolve financial management policy issues. The board's mission is to advise the CFO on issues that are highly complex, sensitive, crosscutting, and/or departmental in scope and that have alternative solutions. The Energy Financial Policy Advisory Board comprises the five CFO Headquarters office directors as permanent members and five field CFOs as rotating members for 2-year terms. The Director of the Office of Financial Policy serves as permanent chairperson. The board held its organizational meeting in March 1992 and finalized its operating procedures in April 1992. It held three regularly scheduled meetings, in June and November 1992 and May 1993.

CASH MANAGEMENT

In the area of cash management, the Department continued to improve operations through the Travel and Transportation Expense Payment System. New efforts included using travelers checks at selected sites and plans to use automated teller machines to provide cash to travelers. In the area of debt collection, the CFO established accountability procedures and published guidance regarding monitoring delinquent employee payments for travel charge-card purchases. In addition, the Department completed its fifth year of reporting delinquent debts to credit-reporting bu-

reaus and to the Internal Revenue Service for offset from income tax refunds. From January 1989 through April 1993, the Department recovered approximately \$373,430 through the Federal Tax Refund Offset Program in the form of voluntary repayments from the debtors and actual tax refund offsets. Also, the CFO provided guidance to concerned DOE offices about procedures for payment of claims involving corporations that have filed for bankruptcy.

DOE continued its efforts to improve payment and collection performance. On-time payments under the Prompt Payment Act increased from 72.6 percent in 1989 to 93 percent in 1993. Employee participation in the payroll direct deposit program increased to 87 percent. Nine field organizations are now using credit cards for small purchases. Monitoring of advances to grantees continued to improve, resulting in significant interest savings to the Government. Accounts receivable reporting was expanded to include annual data on the sources of the Department's receivables and to provide additional detail on employee receivables on a quarterly basis. The Department implemented an automated credit bureau reporting system. Overall, DOE's cash management initiatives saved approximately \$45 million in 1993.

COMPLIANCE AND AUDIT LIAISON

Audit Resolution and Followup

DOE pursues a rigorous audit resolution and followup program that effectively responds to Inspector General and General Accounting Office audits, promptly correcting deficiencies as required by OMB Circular A-50, "Audit Followup." The involvement of senior line managers in developing planned actions for resolving and correcting audit finding ensures the timely resolution of audits. The Departmental Internal Control and Audit Review Council, a senior-level management group, exercises executive-level oversight of the Department's audit resolution and followup process.

In May and November 1993, DOE issued the eighth and ninth editions of the Secretary's *Semiannual Report to Congress on Inspector General Audit Reports*. As mandated by the Inspector General Act Amendments of 1988, these semiannual reports identified the status of final actions taken on audit report recommendations of the Inspector General. The Secretary's reports complemented reports issued by the Inspector General that provided re-

lated audit information. For these two reporting periods, the Department took final action on 10 contract and financial assistance audit reports issued by the Inspector General; only 3 reports await final action. Regarding operational, financial, and preaward audits issued by the Inspector General, the Department effected management decisions on 61 reports and took final action on 56 reports. At the end of the reporting period, 93 audit reports required final action. The Department agreed with the Inspector General auditors' estimates that \$41 million could be put to better use.

Chief Financial Officer Compliance Reviews

DOE implemented a formal Headquarters financial management compliance review program in 1984 to assess field office and contractor compliance with the Department's financial policies and procedures. DOE has conducted 42 reviews since 1984, resulting in more than 860 recommendations for improving financial management practices in such areas as financial systems, cash management, budget formulation, reimbursable work, letters of credit, and internal controls. Followup procedures are conducted on areas previously reported to have deficiencies to ensure that corrective measures have been implemented and that improvements have been made. The Department now performs the reviews on an accelerated schedule and places more emphasis on two activities: (1) evaluating the financial management systems and management controls of its contractors and (2) the oversight of contractors' financial operations performed by the Department's field activities.

Management Control Program

In accordance with the Federal Managers' Financial Integrity Act of 1982, DOE implemented a management control program to evaluate management controls and financial systems. The evaluation relies on self-evaluations and reporting of problems by the Department's senior managers. The Department's major integrated contractors also are required to attest to the adequacy of their controls.

As required by the Federal Managers' Financial Integrity Act, the Secretary annually prepares a report to the President and Congress based on the results of DOE's evaluations of its management controls and financial systems and assurances given by the Department's senior managers. The Secretary's 1992 report identified material weaknesses in 14 areas: environmental compliance, nuclear safety, nuclear waste storage and disposal, weapons complex reconfiguration, contract and project management, infrastructure, nonnuclear safety and health, audit coverage, quality budget estimates, staffing deployment, quality assurance, safeguards and security, reimbursable programs, and information resources management. Two weaknesses reported in 1991, financial management and contractor employee whistle-blower protection, have been corrected sufficiently and are no longer considered material. DOE has developed a corrective action plan for each of the 14 material weaknesses, and the Departmental Internal Control and Audit Review Council will closely monitor the implementation of these plans. Corrective actions will be tracked through to completion.

To strengthen the quality of the management control program, the Department established a process improvement quality team to identify opportunities for increasing customer satisfaction and for streamlining the program. In keeping with the executive order on reducing Government regulations, the team will work to eliminate nonvalue-added procedures from program directives. The quality team is composed of selected representatives from Headquarters and field organizations, as well as stakeholder participants from the Office of Management and Budget and the Inspector General.

AUDITED FINANCIAL STATEMENTS

Historically, DOE has published audited financial statements for seven entities. In support of the Chief Financial Officers Act of 1990, the Department completed audited financial statements for 3 additional commercial-type entities during 1992 and 1 additional entity during 1993, resulting in audited financial statements for 11 entities in 1993. DOE prepared these statements in compliance with the OMB Circular 93-02, "Form and Content of Agency Financial Statements." As appropriate, the statements incorporated several improvements, including the reporting of performance measures and expanded overviews.

FINANCIAL MANAGEMENT DEVELOPMENTAL PROGRAM

Before 1992, DOE did not have a comprehensive developmental program for financial management personnel; each office independently developed and executed its own program. As a result, some individuals were not receiving the training they needed to perform their assigned functions, and there were several instances where a sufficient cadre of well-qualified candidates was not available to fill vacancies in critical financial management positions.

In May 1991, the Secretary directed the Departmental CFO to establish a training program for financial managers at all career levels directed toward developing senior financial management professionals who could apply comprehensive and thorough financial management techniques to the budgetary and fiscal management of DOE's programs. This direction fully complemented the CFO Act, which requires the Departmental CFO to "direct, manage, and provide policy guidance and oversight of . . . training of personnel to carry out financial management functions." The Acting CFO therefore designated one of her senior managers as responsible for developing and implementing a comprehensive developmental program to satisfy the directions of the Secretary and to fulfill the intentions of the CFO Act.

DOE achieved notable progress in 1992. A group of subject-matter experts from Headquarters and the field created an innovative approach to employee development, which the Department formally published and implemented on June 4, 1992, as the Financial Management Developmental Program (FMDP). The primary components of the FMDP are as follows:

1. Policies and procedures fully describe the goals and operations of the FMDP; all finance offices must offer the program to their staffs, but employee participation is voluntary.
2. Five detailed curriculums provide required and elective developmental activities for accountants (entry and journeymen), budget analysts (entry and journeymen), and financial managers. These curriculums identify activities considered to be necessary to ensure that employees have adequate knowledge, skills, and abilities to perform the complex tasks that may be assigned to them. Most of the activities relate to on-the-job experiences; these are to be supplemented with some classroom activities and self-study courses. As employees com-

plete the requirements of a curriculum, the Departmental CFO will issue formal completion certificates.

3. A compendium describes each developmental activity by providing information on the target audience, the normal length of the activity, and detailed descriptions and contents.
4. A requirement has been established for an individual development plan for each participating employee. A team of CR employees developed detailed procedures, including step-by-step instructions and a user-friendly personal computer disk that housed the suggested plan format.
5. A new training professional position has been established in the Departmental CFO's resource management staff to oversee the daily operation of the FMDP.

DOE has made considerable progress since the FMDP's implementation. Two curricula for accounting technicians have been implemented, and two curricula developed for secretaries are being reviewed. Two formal self-study courses (reimbursable work and pricing of products) have been published, and two (construction projects and budget validation) are in process. Specific training courses on the Department's standard accounting system are nearing completion, and an 80-hour introductory training course on financial management is being developed. These courses should be implemented in late 1994.

The Department also has made considerable progress in improving financial management, but much remains to be done. Major future deliverables include curriculums for other occupational series within the CFO organizations; several classroom courses, including a 40-hour introduction class for all financial management personnel; and approximately 30 self-study courses.

The FMDP has been well received within the Department. More than 89 percent of all targeted employees have chosen to participate, and about 90 percent of these have formal individual development plans that include the FMDP requirements.

The Acting CFO approved the issuance of 113 certificates to employees who have completed the requirements included in one of the established curricula. These included 9 financial managers (level 3), 18 accountants (level 2), 4 budget analysts (level 2), 56 accountants (level 1), and 26 budget analysts (level 1). Other Federal agencies have also expressed considerable interest in this program, and several are planning to implement the FMDP for their own purposes.

CHAPTER 17

PUBLIC AND CONSUMER AFFAIRS

INTRODUCTION

The Office of Public and Consumer Affairs manages and oversees all of DOE's public and consumer affairs efforts, comprising public information and consumer support activities, press services, speechwriting, and editorial services in accordance with the Secretary's policy of openness. The Office of Public and Consumer Affairs articulates the Nation's energy policy and serves as the chief voice for the Secretary, the Deputy Secretary, and the Under Secretary. The office also provides policy advice and support for timely dissemination of public information and for development of effective outreach strategies routinely and during emergencies.

As the Department's central point of contact with the national print and broadcast media, the Office of Public and Consumer Affairs develops public information and outreach strategies and arranges press conferences, interviews, and meetings with media and stakeholder groups. The office oversees the development of press releases, factsheets, and speeches on critical and sensitive national energy policies and programs. Staff maintains daily contact with the field offices and contractors to assure a timely flow of information and news within the Department and to the public.

The Office of Public and Consumer Affairs oversees the drafting of speeches, letters to the editor, and magazine articles; the development of audiovisual materials; and the dissemination of exhibits and publications produced within the Department or by contractors.

In the summer of 1993, the Office of Public and Consumer Affairs developed a new structure that would eliminate unnecessary layering and duplication of functions,

and would improve communication and overall effectiveness. The new structure, approved in November 1993, provides a solid foundation for improving services while restraining costs, in line with the Administration's goals for Reinventing Government.

CONSUMER AND PUBLIC LIAISON

The Office of Consumer and Public Liaison is the central coordination point for the Department's communication and outreach activities to consumer, business, and community groups.

In 1992 and 1993, the Office of Consumer and Public Liaison was the primary liaison between the Department and more than 1,100 industry, environmental, consumer, conservation, business, labor, farm, scientific, engineering, technology transfer, and educational associations. The office provided a channel for interactive stakeholder communication and response concerning departmental policies, programs, and priorities; mechanisms included public meetings, mass mailings, telephone calls, and facsimile transmissions. The office serves as the coordinator for internal program and field offices with other Federal agencies and with stakeholder groups. The office also produced nationally distributed "consumer news update" radio programs on a monthly basis and public service announcements. Additionally, the office provided "casework" services to more than 500 individual consumers who wrote with specific energy-related problems or requests.

In 1993, under the Secretary's restructuring of the Department, the Office of Consumer and Public Liaison assumed added responsibility as the coordination point

for public involvement activities across the Department. The office provided policy support to senior management and strategic support to program offices in developing and implementing public involvement activities responsive to legislative mandates, community concerns, and the national interest.

The Office of Consumer and Public Liaison also actively participated in the National Energy and Aging Consortium, Inc., a network of more than 40 organizations representing both the public and private sectors. Through the consortium, the office was able to strengthen its interaction with organizations working specifically to meet the energy needs of the elderly. In December 1992, in response to a request by the Senate Special Committee on Aging, the office conducted a comprehensive assessment of major departmental activities that directly affect the lives of older Americans and wrote a detailed report on its findings.

In September 1992, the Office of Public Affairs established a Speakers Bureau which was moved into the Consumer and Public Liaison Division under the 1993 reorganization. The Speakers Bureau provides surrogate speakers in lieu of the Secretary, Deputy Secretary, and Under Secretary, and compiles and distributes a weekly calendar of senior officials' speaking engagements.

The office continued to work closely with the U.S. Office of Consumer Affairs and other Federal agencies to address consumer issues by helping to plan and coordinate consumer activities during National Consumer Week and by supporting the development and distribution of the *Consumer's Resource Handbook*.

PRESS ACTIVITIES

The Deputy Press Secretary is the Department's chief spokesperson, handling news media activities for the Department of Energy. The Press Services Division provides guidance to DOE Headquarters and represents DOE to other agencies.

Press Services answers inquiries from the news media and prepares releases, media advisories, factsheets, background information and papers, statements, talking points, feature stories, and other materials for the news media and for the Secretary and other senior officials to use when talking with the media. The division works with the Research and Special Projects Division on Secretarial speeches and visual aids.

During 1992 and 1993, the Press Office organized an estimated 70 national press conferences; prepared and dis-

tributed approximately 650 press releases; and arranged more than 900 interviews for departmental officials.

The Press Services Division coordinated press conferences for the Secretary, the Deputy Secretary and other departmental officials, including conferences on DOE's 1992 budget request, the Energy Policy Act of 1992, the strategic planning process, the 1993 budget priorities reordering and reorganization of the department, and the whistleblowers' safety press conference. The division was also responsible for major press announcements such as the global climate challenge, the U.S. car challenge, the natural gas and oil initiative, the "openness" initiative, spent fuel storage sites, and the selection of projects under Round 5 of the clean coal technology program. The Press Services Division, in conjunction with the Principal Deputy for Public and Consumer Affairs, published the 1993 Department of Energy Accomplishments report for use by the media and to provide information to the public (See Bibliography).

RESEARCH AND SPECIAL PROJECTS

The Research and Special Projects Division was established in May 1993. It assumed the functions of what was formerly the Speechwriting Office, and provides support to the Secretary, Deputy Secretary, and Under Secretary in defining, explaining, and promoting the policies and programs of the Department. The Division performs research and maintains relevant data and historical information, prepares speeches, sound bytes, audiovisual presentations, talking points, editorial services and all other forms of communications support for presentation and publication.

Editorial services, established in September 1991, and later incorporated into the Research and Special Projects Division, performs outreach that includes editorials in support of DOE policies and programs, reactive letters to the editor, and informational articles for magazines and trade journals on topics ranging from the National Energy Strategy to technology transfer. From its inception, the office has prepared a total of 307 written pieces, 244 of which were sent for publication in major newspapers and magazines; 81 of those 244—about 33 percent—have been published. In addition, Editorial Services is the Public Affairs point of contact and distribution center for Government Accounting Office and Inspector General audits and reports.

In 1993, the Office of Research and Special Projects established a comprehensive research data base of technology transfer "success stories" for use by the President, Secretary, Deputy Secretary, and Under Secretary in public speaking events and news conferences.

The office also developed a research library of speech transcripts, audiovisual aids (overhead, flip charts, storyboards, video), background briefings, significant press clippings, publications, and other materials prepared for use by the Secretary, Deputy Secretary, and Under Secretary.

More than 200 speeches and public presentations and more than 60 writing and editing projects have been prepared for the department's principal officials. This office also compiled and edited the 100-day report on DOE accomplishments for the White House (see Bibliography).

PUBLIC INFORMATION ACTIVITIES

The Public Information Division responds to general public inquiries about the Department and national energy policy. It is also responsible for overall policy for and management and review of all departmental publications, exhibits, and audiovisual products. It responds to the Office of Management and Budget directives that establish and oversee a central management system for periodicals, pamphlets, and audiovisuals. When requested, the office reports costs and cost-reduction actions for all departmental public communications products to the Office of Management and Budget.

The Public Information Division runs an open call-in and walk-in public inquiries service where the general public can obtain information about DOE. In 1992, Public Information responded to approximately 11,000 calls, 2,300 letters, and 8,000 walk-in visitors; in 1993, approximately 10,500 calls, 2,000 letters, and 7,000 walk-in visitors.

The Public Information Division publishes the monthly departmental news magazine, *DOE This Month*, and assembles and distributes to senior staff daily newspaper and weekly magazine clippings concerning the Department's mission and activities. The office also loans printing negatives of certain DOE publications, like *Tips for Energy Savers*, to State Energy Offices, utilities, and other organizations that wish to reprint large quantities at their own expense. For example, in 1992 the North Carolina Department of Economic and Community Development reprinted 10,000 copies of *Tips for Energy Savers*.

The Public Information Division coordinates public events and programs, such as Energy Awareness Month. In addition, the office assists other departmental elements with such programs as Public Service Recognition Week and the Combined Federal Campaign by developing information materials and publicizing the events.

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CHAPTER 18

CONGRESSIONAL AND INTERGOVERNMENTAL AFFAIRS

INTRODUCTION

Throughout 1992 and 1993, the Office of Congressional and Intergovernmental Affairs was responsible for developing, managing, and coordinating departmentwide activities and interactions between the Department and Congress, state and tribal governments, and other Federal agencies. The office served as the central point of contact to ensure that the Administration's and Department's energy goals and objectives were clearly and concisely communicated and that the views of those affected by the Department's actions were considered in policy and program decisions. Through these efforts, the office has led the Department in improving its relations with state, local, and tribal governments and other Federal agencies.

CONGRESSIONAL AFFAIRS

The Office of Congressional and Intergovernmental Affairs coordinated all activities between the Department and Congress, including providing legislative support for both departmental initiatives and energy legislation proposed by Congress and working closely with senior departmental officials and Members of Congress and their staffs on energy issues both before and after hearings. The office participated in briefings and meetings at the committee and subcommittee levels for the Department's authorizing, oversight, and appropriations committees and with Congress and state, local, and tribal governments regarding the Department's implementation of energy policy. The office also scheduled and prepared the Secretary and

other principals for hearings before congressional committees and meetings with Members of Congress and state, local, and tribal governmental officials. In their role as intermediaries with Members of Congress and state and tribal governments, staff members attended more than 18,500 briefings and meetings and provided departmentwide liaison representation coverage.

The office also monitored, tracked, and analyzed all appropriate energy-related legislation for the Offices of the Secretary, Deputy Secretary, and Policy and for line offices. In addition, the office informed key congressional leaders and their staffs, committee and subcommittee chairpersons, and ranking minority members about departmental positions, activities, and actions.

The Office of Governmental Relations worked with the various departmental organizations to coordinate all congressional activities relating to DOE policies and programs. The staff managed preparations for the hearings, attended and reported on those hearings, and conducted posthearing followups. The staff also was responsible for hearings that did not involve departmental witnesses but still affected energy issues, and for attending and reporting on energy-related markups, conferences, and floor actions.

During its second session, the 102nd Congress passed the Energy Policy Act of 1992, the most ambitious national energy policy legislation in more than a decade, and one that contained key elements proposed in the Department's National Energy Strategy. Another major accomplishment was the passage of the Waste Isolation Pilot Plant Land Withdrawal Act of 1992. Additionally, the issue of Federal facilities' compliance with environmental laws was resolved by the passage of the Federal Facility Compliance Act of 1992. The office's efforts for these legislative issues also included arranging briefings

for program officials with Members of Congress and their staffs on the Superconducting Super Collider and supporting the Department's budget request and initiatives. The office also provided extensive support and assistance in the negotiation of several other critical energy issues.

The office was involved with congressional actions on the FY 1993 Department of Interior and Related Agencies Appropriation Bill, which provided \$815.8 million in budget authority for fossil energy research and development, the Naval Petroleum and Oil Shale Reserves, energy conservation, economic regulation, emergency preparedness, the Strategic Petroleum Reserve, and the Energy Information Administration. Although no Resource Conservation and Recovery Act-related legislation (other than the Federal Facility Compliance Act) was passed in the 102nd Congress, there was extensive congressional consideration of Resource Conservation and Recovery Act issues, many of which would have directly or indirectly affected the Department.

The FY 1993 Energy and Water Development Appropriation Bill, with which the office was also involved, provided \$17.1 billion in budget authority for Energy Supply Research and Development, Uranium Supply and Enrichment, General Sciences and Research, the Nuclear Waste Fund, the Isotope Production and Distribution Fund, Atomic Energy Defense Activities, Departmental Administration, the Office of the Inspector General, power marketing administrations, the Federal Energy Regulatory Commission, and the Geothermal Resources Development Fund.

Staff also continued to work on the 1994 Department of Interior and Related Agencies Appropriation Bill and the 1994 Energy and Water Development Appropriation Bill in support of the Clinton Administration's budget priorities. As standard liaison procedure, the Office of Governmental Relations arranged the congressional staff briefings presented by senior departmental officials for the Department's proposed budget submissions. Other major pieces of legislation with which the office was actively involved included the Department's component of the FY 1993 and FY 1994 Defense Authorization bills and technology transfer bills affecting DOE national laboratories.

During 1993, the President submitted 15 nominations for departmental posts to the Senate. Staff worked closely with the nominees throughout the nomination process, advising them on congressional and policy issues, scheduling courtesy visits with members of cognizant Senate committees, and providing liaison activities through confirmation hearings and committee approval, leading to fi-

nal Senate confirmation. All Presidential nominees for the Department were approved.

During the second session of the 102nd Congress, the office led the preparation of departmental witnesses, who testified 125 times at 88 hearings before 93 congressional committees and subcommittees (5 of those hearings were joint hearings). Along with these hearings, the office coordinated the Department's responses to more than 685 hearing-related documents, which included prehearing questions and answers (66), posthearing questions and answers (474), inserts for the record (76), and reviews of official transcripts (69). In addition, there were two confirmation hearings during this session: one for the Deputy Secretary and another for the Under Secretary and the Assistant Secretary for Domestic and International Energy Policy.

During the first session of the 103rd Congress, 148 departmental officials presented testimony at 97 hearings. As in 1992, the office coordinated all testimony before Congress for hearings that required review by both the Department and the Office of Management and Budget. In addition, the office coordinated the review of 242 inserts for the record and 1,065 answers to followup questions after those hearings.

The office also performed research and analysis activities and provided senior departmental officials with comprehensive information, collection, and dissemination and indepth legislative tracking and analysis. To ensure that officials were aware of congressional and other intergovernmental concerns, the office prepared briefing papers and background books. In addition, the office developed and implemented more than 400 communications plans to ensure that the Department promptly notified Members of Congress, governors, tribal leaders, mayors, and other groups of major policy and program announcements.

The Office of Governmental Relations provided liaison support for the five energy components of the President's Reinventing Government legislative proposal submitted to the House and Senate in the first session of the 103rd Congress. Meetings and briefings were conducted with staff from the Senate Energy and Natural Resources Committee and the House Natural Resources Committee on these proposals; and Department officials testified before the Senate committee. The House Natural Resources Committee reported out the Alaska Divestiture bill; action is still pending in the Senate on these proposals.

The Office of Governmental Relations reviewed more than 2,000 Departmental responses to congressional correspondence for concurrence in policy and subject matter.

INTERGOVERNMENTAL ACTIVITIES

The Office of Congressional and Intergovernmental Affairs works closely with the intergovernmental community on a wide range of national and regional issues and ensures that the Department considers their views when formulating national energy policies and programs. In 1992 and 1993, the office represented the Department at major national and regional meetings of elected officials on energy policy matters and consulted with senior departmental officials and program offices at Headquarters and in the field on intergovernmental aspects of energy policies, programs, regulations, and the Administration's Federalism Initiative. The office also managed interagency activity relating to energy programs of mutual interest to other Federal departments or agencies.

During 1992 and 1993, the office informed elected officials about, and obtained constituent input and views on, the issues relating to the implementation of the Energy Policy Act; initiated implementation of a departmental American Indian policy (DOE was the first cabinet-level agency to adopt a formal American Indian policy statement); and engaged in various activities relating to nuclear waste storage, transportation, and disposal, environmental cleanup and waste management at Department of Energy facilities, downsizing of the nuclear weapons complex, and the Clean Coal Technology Program. The staff worked with national organizations such as the National Governors Association and other state, local, and tribal groups on the development of their national energy policy positions.

On behalf of the White House, office staff coordinated the implementation of a memorandum of understanding between the Department, the Department of Defense, the Environmental Protection Agency, the Department of the Interior, and the Western Governors Association concerning the development and demonstration of technologies for environmental cleanup. Additionally, the staff led a departmental team that represented the Department on a Keystone work group (named after the Federal Facilities

Environmental Restoration Dialogue Committee (Keystone) Report) charged with recommending ways for improving state and local government participation in environmental restoration decisions at Federal sites.

The office began additional outreach initiatives, both separately and in conjunction with DOE program offices, to increase interaction of state, local, and tribal officials with the Department. The office has provided daily intergovernmental policy advice and support to departmental program and operations offices through more than 2,500 personal contacts, and has reviewed more than 1,000 program proposals, concurrences, and correspondence for intergovernmental impact.

The office has been increasingly active in American Indian activities. In conjunction with the Office of Public and Consumer Affairs, the Department published a quarterly newsletter, *The Energy Messenger*, for distribution to all federally recognized tribes, major national and regional American Indian organizations, state American Indian commissions, other Federal agencies, Congress, and individuals interested in American Indian energy issues. It also conducted three workshops for departmental field and Headquarters staff who work with tribes to acquaint them with energy-related issues of concern to American Indian tribes and to better prepare them to work with tribes. The office established, in conjunction with energy-resource Indian tribes, a departmental joint working group on Indian energy-resource development to develop strategy and program guidance on implementation of title XXVI, "Indian Energy Resources," of the Energy Policy Act of 1992 and related issues. It also established, in conjunction with the Navajo Nation, working groups to address two significant pilot projects proposed by the Navajo Nation for funding under title XXVI.

Because state, local, and tribal governments are affected by Federal energy policies, the Department has taken a proactive role in involving these levels of government in its energy initiatives. Recognizing the energy differences between states and regions, the Department will continue to work closely with these officials and emphasize issues that will meet their particular needs.

CHAPTER 19

ENVIRONMENT, SAFETY, AND HEALTH

INTRODUCTION

The Office of Environment, Safety and Health (EH) helps the Department meet its national security and scientific objectives in a safe and environmentally sound manner by developing and coordinating audits, appraisals, and assessments to ensure compliance with applicable environmental protection, radiation safety, and worker safety and industrial hygiene requirements, and with aspects of public health and safety that address epidemiology and radiological protection. EH directs its oversight activities to areas other than nuclear facility safety, such as inspecting and evaluating the effectiveness of the Department's safeguards and security policies, programs, and implementation in the field. Safety certification of packaged shipments of the Department's radioactive materials also falls under EH's purview.

EH complements these oversight activities by providing guidance to field installations and program operations with respect to the environment, safety (nonnuclear), health, and quality assurance. It is the liaison with Federal agencies such as the Environmental Protection Agency (EPA) and Occupational Safety and Health Administration (OSHA) concerning regulatory efforts and specific actions of those agencies that may affect Department operations. EH also ensures that environmental, safety, and health goals are incorporated into all levels of the Department's decision-making process. The following sections discuss EH's activities in these main areas: environment, safety and quality assurance, health, nuclear safety, security evaluations, and special projects.

ENVIRONMENT

The Office of Environment's mission is to advise EH's Assistant Secretary and senior departmental program officials on the Department's conformance with environmental laws and principles, establish departmentwide environmental policies and requirements, assess compliance with internal and external requirements, and help programs comply with environmental laws. The office carries out this mission primarily through four programs: Environmental Compliance, Environmental Guidance, Environmental Audit, and National Environmental Policy Act Oversight.

Environmental Compliance

The Environmental Compliance Program establishes and promotes environmental protection policies and DOE complexwide strategies for attaining and maintaining environmental compliance at DOE facilities. The program also provides DOE organizations with policy direction and technical support to help resolve significant environmental compliance issues. The program focuses on air and water pollution control; hazardous, mixed, and radioactive waste management; cleanup and remedial actions; and other environmental areas of concern to EPA and other regulatory agencies.

The program continued to implement systems for tracking enforcement activities (such as notices of violations,

warning letters, and consent orders and agreements), and in 1993 initiated a new tracking system for multimedia Federal facility inspections at DOE sites conducted under a new EPA initiative. The program also continued to resolve several complex, crosscutting compliance issues concerning mixed-waste streams, such as developing strategies for managing materials and waste that may be regulated by the Atomic Energy Act and other environmental laws (such as the Resource Conservation and Recovery Act). These strategies will be discussed with the appropriate regulatory agencies. The program also participated in the development of, and prepared implementing guidance for, a new Secretarial initiative regarding management procedures for violations of environmental requirements and related fines and penalties.

The program provided policy direction and technical assistance for negotiating significant compliance and cleanup agreements with EPA and the states at major DOE facilities, including Hanford, Rocky Flats, and Los Alamos. The program also provided independent oversight and monitoring of implementation activities under existing compliance and cleanup agreements and coordinated the review and resolution of significant site-specific environmental compliance issues within DOE and with EPA.

In 1993, program staff attended nondepartmental forums for Federal agencies, state organizations, and environmental groups to analyze complex Federal facility compliance issues and to improve communication and coordination among organizations. The program also provided policy support and technical assistance for departmental meetings with congressional staff on new Federal environmental compliance legislation and helped develop policy and compliance guidance for DOE Headquarters and field offices to meet the requirements of the Federal Facility Compliance Act.

Environmental Guidance

The Environmental Guidance Program issues guidance documents and conducts training workshops to enhance departmentwide understanding of environmental laws and regulations that apply to DOE operations and projects. It also establishes departmentwide environmental policy for those operations and projects and develops, in coordination with affected DOE elements, the departmental position on other agencies' environmental rulemaking efforts that affect DOE operations and projects.

The Environmental Guidance Program developed new policies and guidance documents in 1993 for the protec-

tion of air, water, and cultural resources; the protection of the public and the environment from radiation; the cleanup of contaminated sites; the treatment, storage, and disposal of hazardous and mixed waste; and pollution prevention. Significant accomplishments included the following:

1. Issuance of guidance manuals on the corrective action program, the preparation of waste analysis plans, and the management of hazardous waste containers and storage areas under the Resource Conservation and Recovery Act
2. Publication of a proposed rule for radiation protection of the public and the environment (10 CFR part 834) for public comment
3. Development of guidance for implementing title VI of the Clean Air Act (Stratospheric Ozone Protection), and a report to the Office of Management and Budget highlighting the Department's efforts to minimize the procurement and use of ozone-depleting substances at its facilities
4. Publication of a report on 1990 inventories of low-level and mixed low-level radioactive waste at DOE and commercial facilities
5. Issuance of a guidance manual on the management of polychlorinated biphenyls (PCBs) under the Toxic Substances Control Act (TSCA)
6. Development of guidance on the Department's participation in the Industrial Toxics Reduction Program (commonly referred to as the 33/50 Pollution Prevention Program) and toxic chemical release inventory reporting under the Emergency Planning and Community Right-to-Know Act (EPCRA)
7. Issuance of a series of information briefs and guidance to enhance DOE awareness of the importance of cultural resources at DOE facilities and statutory responsibilities

The program also conducted a series of workshops for Department and contractor personnel with environmental compliance responsibilities. Topics included an overview of environmental laws and regulations; the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) remedial investigation-feasibility study process; the Resource Conservation and Recovery Act (RCRA) corrective action process; the RCRA definition of solid and hazardous wastes; RCRA and CERCLA program orientations; and toxic chemical release inventory reporting.

Environmental Auditing

Tiger Team assessments (comprehensive assessments of environmental, safety, and health (ES&H) compliance and management) at 35 major facilities were an important component of the Department's 10-point plan instituted in 1989 to achieve full accountability and compliance with ES&H laws. The Environmental Audit Program conducted the environmental component of these assessments; the last five were completed and final reports issued in 1992.

The Environmental Audit Program also provides the technical support and leadership for the environmental component of ES&H progress assessments. These progress assessments measure improvements in specific technical programs and ES&H management, based on the key trends identified in the Tiger Team report for that facility. Specifically, the assessments evaluate the effectiveness of the facility's line managers in developing, establishing, and implementing, on a sustained basis, their ES&H responsibilities. The Environmental Audit Program supported five progress assessments in 1992, and seven in 1993.

The program conducted three comprehensive baseline environmental audits and three environmental management assessments in 1992. In 1993, the program conducted comprehensive baseline environmental audits at three additional facilities and environmental management assessments at three "preoperational" facilities (the Continuous Electron Beam Accelerator Facility, the Waste Isolation Pilot Plant, and the Superconducting Super Collider). Environmental management assessments were also conducted at three major facilities that included technical-compliance review for selected environmental disciplines. The baseline audits are performed at DOE's smaller facilities, which were not assessed using the Tiger Team process. The audits evaluate air, soil, surface water, groundwater, waste management, toxic and chemical materials, radiation, quality assurance-quality control, and inactive waste sites and releases against applicable environmental requirements, DOE orders, and best management practices. The management assessments, which cover activity within DOE program support offices or their components, take a broad, programmatic view, focusing on infrastructure, systems, programs, and tools to manage environmental issues, rather than specific regulatory compliance.

In 1993, the Environmental Audit Program conducted its first two "Special Issue Reviews" of crosscutting, complexwide environmental issues. The topics reviewed were quality assurance management in environmental data and pollution prevention management. In addition to the Tiger Team assessments, progress assessments, baseline

audits, and management assessments, the program also conducted a training course on environmental auditing every 2 months. This course has been designed to assist DOE Headquarters and field personnel in performing environmental oversight activities by providing a detailed understanding of the environmental audit and assessment program. The program also trained DOE and contractor personnel in environmental management assessments as part of an environmental auditing seminar held by the Office of Environmental Audit, and also presented the training to approximately 20 other Federal agencies in coordination with the Environmental Protection Agency.

National Environmental Policy Act Oversight

The National Environmental Policy Act (NEPA) Oversight Office assists DOE program and operations offices with NEPA compliance, including planning and reviewing environmental assessments and environmental impact statements, through its NEPA Oversight Program, which supports DOE compliance with NEPA and other related environmental review requirements and also oversees NEPA-related activities in all DOE program areas. Because compliance with NEPA is a prerequisite for implementing most of the Department's programs and projects, timely and adequate NEPA documents are critical to meeting the Department's objectives.

The Department of Energy currently has more than 250 NEPA environmental reviews in progress. In 1992 and 1993, the office recommended to the EH Assistant Secretary the approval of 164 environmental assessments and 8 environmental impact statements.

In 1992 and 1993, the NEPA Oversight Office continued to develop general NEPA compliance policy and guidance, review highly complex documents for technical adequacy and accuracy and appropriateness of scientific methodology, review proposed DOE projects and programs for potential applicability of NEPA and related environmental review requirements (such as endangered species, wetlands, and floodplain protection), help prepare NEPA documents and related environmental documents, provide litigation support, coordinate with other Federal agencies, and conduct general NEPA workshops and training courses and periodic meetings for program and field office NEPA compliance officers.

The Department published a final rule for NEPA implementing procedures in the *Federal Register* (57 FR 15122) on April 24, 1992, which was codified in the *Code of*

Federal Regulations (10 CFR 1021). The rule broadens public participation and information access, and requires DOE to notify host states and American Indian tribes of determinations to prepare an environmental assessment or environmental impact statement and allow them to comment on environmental assessments before they are approved by DOE. The rule also enhances departmental efficiency by including a revised and expanded list of typical classes of actions, including categorical exclusions (classes of actions that normally do not require either an environmental assessment or an environmental impact statement). A revision of DOE's internal procedures and assignments of NEPA responsibilities and authorities (DOE 5440.IE, "National Environmental Policy Act Compliance Program") was issued on November 10, 1992, to help implement the new rule.

In May 1993, the NEPA Oversight Office issued "Recommendations for the Preparation of Environmental Assessments and Environmental Impact Statements," a guidance document that helps NEPA-document preparers and reviewers to focus on significant environmental issues, adequately analyze environmental impacts, and effectively present the analysis to decision-makers and the public. This document was commended by the Council on Environmental Quality. (The office also prepared and disseminated an accompanying training curriculum.) The office also issued guidance on complying with floodplain and wetlands review requirements, strengthening the role of DOE NEPA compliance officers, integrating pollution prevention with NEPA planning activities, and alternative actions for analysis in sitewide NEPA reviews in 1992 and 1993.

SAFETY AND QUALITY ASSURANCE

Introduction

The mission of the Office of Safety and Quality Assurance, the Department's advocate for effective safety and health programs in the workplace, is to prevent and mitigate workplace injuries and deaths. The office accomplishes this through policy and guidance development, technical assistance, and independent oversight of line management. Line management is responsible for developing and implementing cost-effective strategies for occupational safety and quality assurance programs.

The Office of Safety and Quality Assurance's mission and functions have evolved over the past 5 years, from an oversight organization focused principally on the status of operating contractor *compliance* with applicable safety and health rules and regulations, to an independent entity that advises the Secretary and cognizant secretarial officers regarding the effectiveness of their workplace safety programs and management *performance*. The office must understand the Department's programs, goals, and circumstances to understand the "big picture" in which it operates and must also act as a catalyst for positive change through policy development, program review, and technical assistance to line managers and appropriate staff.

The office continued to develop major programs to address worker safety and health in 1992 and 1993. Many of these programs reflect the 1990 OSHA evaluation of the Department's occupational safety and health program for its government-owned, contractor-operated facilities. Though much of the office's effort in the last 2 years was directed toward establishing policy, requirements, and guidelines to help line managers assess their compliance with Federal, state, and Department requirements, the office also increased efforts toward providing technical assistance.

Because the office does not manage line programs, its success depends on its ability to engage line management constructively, through an assortment of programs, so that managers' expertise is strengthened and safety and health programs, as well as worker safety performance, are demonstrably improved. Success must be gauged by how well workers and the public are protected and how well mission success is achieved.

The Office of Safety and Quality Assurance addresses its mission through three offices and two staff organizations. The three offices—Occupational Safety, Performance Assessment, and Risk Analysis and Technology—divide up the responsibilities of occupational safety policy development, technical assistance to line programs, performance assessment, aviation and transportation, and risk analysis. The two staff organizations are responsible for monitoring field activities on a continuous basis (Site Representative Program) and providing a budget and program evaluation function on behalf of the Secretary of Energy (Program Evaluation).

Given the current status of the Department's occupational safety and health programs and the new issues that must be addressed, the Office of Safety and Quality Assurance serves as an important resource to serve the needs

of the Department and its workers. During the past 2 years, the office initiated the following programs:

1. Safety and health resource planning and management assistance through the safety and health 5-year plan was expanded, with independent budget assessment for the Secretary.
2. For the Voluntary Protection Program, exemplary ("star status" programs per OSHA format) will be solicited from all sites. The Secretary approved seeking applications for this model program.
3. For Type-A Accident Investigations, a new investigation process was put into place with the Office of Environment, Safety and Health as the lead office. New investigation protocols have been developed.
4. The transfer of the Federal Employees Occupational Safety and Health Program to the Office of Environment, Safety and Health was completed. This will increase the emphasis on Federal employee safety and health issues for the 18,500 employees of the Department. The first walk-through surveys of all Headquarters facilities was completed in December 1993. The findings are sent to the Office of Human Resources and Administration for distribution to appropriate Cognizant Secretarial Officers.
5. A new office to determine departmental aviation safety policy, the Aviation Operations Policy Office, was created within the Office of Safety and Quality Assurance and is currently assessing the status of such policy. The office serves as the primary liaison with other agencies.
6. The Hanford Safety Team began an extensive mentoring effort to help the Hanford tank farm with its safety and health programs.
7. Five pilot programs of model safety efforts were completed under the Worker Protection Pilot Program.
8. The Behavior-Based Safety Pilots initiative will support and integrate pilot programs in cooperation with Nevada, Hanford, Idaho, Pantex, and Sandia and calls for using a total quality management approach to safety issues.
9. Specialized technical assistance was provided to the Office of Environmental Restoration and Waste Management to enhance worker safety and health during environmental restoration and waste management operations and to accomplish the surplus facility inventory and assessment.

Program Evaluation

The Program Evaluation staff oversee and coordinate departmentwide safety and health resource planning and provide management assistance to all sectors of the Department, including the cognizant secretarial officers, operations offices, and operating contractors. The results of these activities are reflected in annual safety and health 5-year plans, produced by each cognizant secretarial officer. These plans address all facets of safety and health, including nuclear safety. Their purpose is to rationally prioritize safety and health activities, leading to cost-effective strategies and programs that significantly reduce risk to workers and the public.

The first safety and health 5-year plan was approved by the Secretary on September 28, 1992. The second planning cycle, which began in 1994, emphasizes obtaining high-quality safety and health data. The second plan will be issued concurrently with the 1995 congressional budget request. Program Evaluation conducts the planning process and related training across the Department's complex, with direct participation by the cognizant secretarial officers, operations offices, and operating contractors. Once a cognizant secretarial officer plan is completed, Program Evaluation and other oversight organizations independently review it to ensure that unacceptable risks are identified and programs funded to eliminate such risks. If programmatic or budgetary problems are identified, this resolution is sought before the Secretary's budget review.

The Program Evaluation staff, representing EH, help the Chief Financial Officer determine whether the cognizant secretarial officer's budget adequately addresses safety and health risks during the internal review budget process. In addition, Program Evaluation uses cognizant secretarial officer and Operations Office data submitted in the safety and health 5-year planning process (for both the first and second 5-year plans) to prepare both the EH budget crosscut and related Nuclear Safety and Occupational Safety and Health budget crosscuts for the Chief Financial Officer.

In 1993, Program Evaluation helped operations offices establish behavior-based safety programs at selected departmental sites and helped develop the Department's surplus facility inventory and assessment project by providing direct technical assistance to the Office of Environmental

Restoration and Waste Management's Office of Facility Transition and Management. In particular, Program Evaluation developed the risk-based prioritization methodology that will be used to evaluate facilities for acceptance.

Program Evaluation is also responsible for ensuring that fiscal and management controls are adhered to within the Office of Safety and Quality Assurance. This task involves conducting ongoing review of fiscal and program management and ensuring that all managers are adequately trained in this regard.

Site Representative Program

The Site Representative Program is a key element in overall efforts to monitor line management's performance in implementing occupational safety programs. The program was initially established in response to a recommendation by the National Academy of Sciences that the Department strengthen its ability to monitor onsite activities that affect environmental, safety, and health (ES&H) issues. The program was restructured in the spring of 1991 to sharpen its focus on overseeing Department line programs for occupational safety.

The site representatives are assigned to five regional offices at Department sites—Savannah River, South Carolina; Oak Ridge, Tennessee; Idaho Falls, Idaho; Rocky Flats, Colorado; and Richland, Washington. The Site Representative Program was regionalized in 1992 to ensure ES&H presence at Department sites within the regions. The primary mission of the site representative is to maintain onsite ES&H presence at key Department sites by routinely monitoring the effectiveness of line programs for occupational safety. In addition, the site representatives support programmatic performance assessments conducted by EH program managers at Headquarters.

The Site Representative Program has concentrated on conducting indepth performance assessments in specific functional areas. These assessments examine the effectiveness of Department line oversight for the functional area and the contractor activities in that area. In 1992 and 1993, the program conducted 85 indepth functional assessments at Department sites. Assessment functional areas included transportation and packaging of hazardous materials, construction safety, hazardous waste operations, hazard recognition and control, fire protection, quality assurance, and a variety of other occupational safety areas.

Small teams (typically one or two people) conduct the assessments over a 3- to 4-week period to minimize the

impact on line and contractor activities. The assessments are documented in reports to the cognizant secretarial officers. These site representative reports document and evaluate line management activities within the functional area assessed and identify programmatic deficiencies and strengths. The responsible line programs identify corrective actions in response to the reports. EH followup assessments verify that line program corrective actions are implemented.

Because the site representative reports are issued to all the cognizant secretarial officers, these officers can compare their own site's performance with other sites in terms of a particular functional area. In addition, the reports become a valuable source of information and lessons learned with respect to how different sites and programs are addressing particular occupational safety areas.

In 1993, the line program representatives from other sites were invited to participate in site representative assessments. This line program representation provided two valuable benefits: (1) training of line program personnel in performance-based occupational safety assessments and (2) an additional method of communicating methods of approach and lessons learned from one site to another and from one line program to another.

Occupational Safety

The Office of Occupational Safety develops and issues occupational safety policies and requirements, provides day-to-day technical assistance to line managers, and fosters enhanced communication among all departmental elements on occupational safety issues. These efforts help strengthen line management's capability and accountability for ensuring the safety and health of all Department contractor workers.

Policies and Requirements

There were several important accomplishments in the area of policy and requirements in 1992 and 1993. A memorandum of understanding (MOU) between the Department of Labor (OSHA) and DOE was signed in August 1992 to establish a mechanism for the two departments to work together to enhance occupational safety and health throughout DOE by sharing technical information and support. During 1993, DOE continued to negotiate with OSHA under the MOU to establish two interagency agreements to provide access to OSHA data and systems in exchange for technical support services from DOE.

The Secretary of Energy authorized the establishment of the Voluntary Protection Program to recognize those contractors that have developed excellent safety and health programs, and informational workshops covering elements of the program were held for Federal and contractor employees. (The program is similar to OSHA's program for private sector employees.) In addition, seven workshops on application procedures for Federal employees have been held, and guidance documents for the Voluntary Protection Program have been completed and will be published when the program is formally initiated. The EH Assistant Secretary has forwarded a memorandum to initiate the Voluntary Protection Program to the Secretary for signature; and an interagency agreement with OSHA, under the MOU, is also being sought to allow sharing of resources with Voluntary Protection Program site evaluation teams.

Several DOE orders continued to undergo extensive revision. The foundation order for the Department's contractor occupational safety and health program—DOE Order 5483.XX, "Occupational Safety and Health Program for DOE Contractor Employees"—identifies program requirements that address management commitment, employee involvement, work-site analysis, hazard prevention and control, hazard abatement, training, recording and reporting of injuries, illnesses, and fatalities, and occupational safety and health assessment. This draft order underwent revision and extensive technical review through an occupational safety and health steering committee. The redrafted order was submitted to the DOE complex for extensive review and concurrence in March 1993. More than 20 briefings and workshops involving active stakeholder participation were held around the country to obtain comments and suggested revisions.

A revision to DOE Order 5480.9, "Construction Project Safety and Health Management," is near completion. This revised order will strengthen worker safety and health measures during construction activities within the Department. A revision to DOE Order 5480.7, "Fire Protection," was promulgated in February 1993 to clarify existing requirements and add requirements for the conduct of fire hazard analysis. In addition, a revision to DOE Order 5480.1b, "Firearms Safety," was also completed; this revision provides specialized safety criteria for training with firearms.

Efforts continued toward the implementation of section 3131 of the National Defense Authorization Act for 1992 and 1993 (Public Law 102-190). This section mandates a training grants award program and charged the Secretary of Energy with enforcing certification of worker protection training for employees involved in hazardous substance response and emergency response activities at

nuclear weapons facilities. EH obtained task group comments and developed an advance notice of proposed rulemaking for publication in the *Federal Register*. The Department will incorporate comments from Department organizations potentially affected and from the general public in preparing the initial rulemaking proposal.

The Pacific Northwest Laboratory's Safety Training Section and the Occupational Safety and Health Administration's Training Institute provided formal training courses for Department contractor supervisors and for occupational safety and health professionals and managers in the areas of OSHA compliance for both general industry and construction. The Department is working vigorously to have contractors and line organizations implement courses tailored to DOE needs. Courses currently being developed are hoisting and rigging safety, lockout/tagout, decommissioning and decontamination, confined-space safety, and environmental restoration and waste management.

The *Department of Energy Interpretations Guide to OSH Standards* was issued in 1992. This guide assists in the timely, accurate, and consistent application of Department-prescribed occupational safety and health standards. The effectiveness of this document was enhanced with the implementation of a toll-free (800) response line. This fully operational system provides real-time information on DOE orders and standards interpretations for Department contractors. All interpretations rendered as part of the response line service are subsequently printed and distributed to registered guideholders.

To meet the growing need for timely and accurate information, the ES&H Technical Information System continued to be developed in a time-phased approach. This automated system provides various ES&H-related data bases for access by health and safety professionals trained in OSHA and general industry standards and other users.

A group of 200 participants began using the ES&H Technical Information System after being introduced to it at the DOE Safety Conference in October 1993. Comments from this group will be evaluated and incorporated into an updated version of the system scheduled for release to an additional 500 users in 1994. In addition, the Office of Occupational Safety began a redesign of DOE's injury, illness, property, and vehicle damage information reporting data base. The redesign will gather and analyze user requirements to ensure the data base is comprehensive and fully responsive to ad hoc queries and specialized studies.

To demonstrate its commitment to safety awareness and information exchange on DOE-wide occupational safety and health activities, the Office of Safety and Quality Assurance continued to publish and expand the coverage

of *The Safety Connection*, a quarterly newsletter with a distribution of 6,800. *The Safety Connection* covers new departmental directions in occupational safety and health and highlights safety initiatives, programs, and activities at Headquarters and in the field. Since its inception in spring 1992, the average total number of pages has quadrupled. In 1993, the office also published a special edition devoted to the second annual DOE Occupational Safety Conference.

In 1992 and 1993, four and six *Safety Notes* and five and four *Bulletins* were published and distributed, respectively, to increase safety awareness throughout the DOE community. *Safety Notes* topics included "Labeling Errors Cause Accidents" and "Vehicle Liftgates—Hazardous Unless Used Cautiously." *Bulletin* topics included "Ladders: Familiarity Breeds Complacency" and "The Fire Below: Spontaneous Combustion in Coal."

Technical Assistance

The Office of Occupational Safety completed and distributed several technical safety guidance documents in 1993. These documents detailed program development and requirements for implementation as identified in the following: *DOE Hoisting and Rigging Manual*, *Electrical Safety Guidelines*, and *Construction Safety Reference Guide*. The office also provided technical assistance by visiting several Department sites. These visits provided guidance to line programs on assessing risks associated with occupational safety and health hazards, prioritizing abatement activities, and managing abatement programs.

The Worker Protection Pilot Program was initiated in November 1992 to assist line programs in developing and sharing occupational and safety compliance program experience at Department sites. In December 1992, Department contractors submitted their model occupational safety and health program elements for possible selection as pilots. A total of 34 proposed pilot programs were evaluated by a Headquarters work group. Of these, 10 were rated as truly outstanding, and the top 4 program element sites were visited to verify their quality. The first cycle of pilots included the following subject areas: chemical management, confined space, electrical safety, and hazard communication.

Performance Assessment

The Office of Performance Assessment conducts independent occupational safety and quality assurance assessments

of line program performance at Department nuclear and nonnuclear facilities. In 1992, the office conducted five reviews of operations office and facility quality assurance programs, two in support of the Site Representative Program and three in support of the cognizant secretarial officers. In 1993, the office conducted one review in support of the Site Representative Program and issued a report on its review of the Headquarters cognizant secretarial officers' implementation of the occupational safety and health requirements.

The office also made occupational safety and health assistance visits to six Department sites to enhance DOE contractor management and employees' awareness of the OSHA regulations. In support of the Tiger Team assessments program, which ended in June 1992, the office has supported 13 progress assessments of corrective actions, 6 of which were conducted in 1993.

Many of the Department's facilities have stopped operations in an effort to correct or improve their environment, safety, and health programs. The Office of Performance Assessment has provided oversight assessment reports of the operational readiness review process for those facilities ready to restart. These reports are used by the Assistant Secretary for Environment, Safety and Health and the Secretary of Energy to determine the operational status of facilities before granting authority to restart.

In conjunction with the office's continuing Quality Assurance Program enhancements, emphasis was placed on counterfeit and suspect parts problems. The office issued a safety notice and developed and presented training at five quality assurance assistance visits. The office also publishes a lessons-learned newsletter, *The Occupational Safety Observer*, to raise awareness within the Department of recent occupational safety incidents and issues and to enhance opportunities for those in the field to apply safety lessons that have been learned.

At the request of the Under Secretary, the office headed the Task Group on Electrical Safety at Department facilities. This task group reviewed the electrical-safety-related performance of a cross section of Department sites. Through field team visits of seven sites, the task group gained insight into the performance of the Department's electrical safety programs and into the root causes of, and corrective actions for, electrical-safety-related incidents. The task group's report, which recommends measures to improve and ensure electrical safety of Department and contractor employees, was issued in January 1993.

After almost 2 years of successes, Occupational Safety and Health Assistance Visits by the Office of Performance Assessment have become a firmly established means for

enhancing the safety and health of the Department's workforce safety programs. Ten DOE sites have received assistance visits, and additional visits are in the planning stages.

These assistance visits, which typically last 1 to 2 weeks, combine the efforts of the Office of Performance Assessment and the cognizant line office (that is, the cognizant secretarial office or operations office). As partners, the two offices work together to examine and improve how both DOE and contractors address occupational safety and health program and management issues. The Office of Performance Assessment acts as a facilitator along with the line programs, with the contractors taking the necessary actions to address and correct problems as necessary. No assessment activity takes place.

Risk Analysis and Technology

The Office of Risk Analysis and Technology provides policy, oversight, and support functions for the Department related to facility safety and risk analysis, natural phenomena hazard mitigation, packaging certification, packaging and transportation safety, aviation safety, dam safety, and nonnuclear safety, including chemical safety and worker safety during environmental restoration and waste management operations. The office also plays a major role in developing departmental policies and guidance to conduct analyses related to nonnuclear system safety. The office interfaces with other Department organizations and external groups regarding these activities and provides oversight for issues related to nuclear and nonnuclear safety to ensure that safety functions are not compromised. The office also provides technical assistance to support line organizations in the implementation of their programs.

Safety Analysis

In 1992 and 1993, the office reviewed safety analysis and evaluation programs and activities, technical safety requirements, and hazard and risk analysis programs for 6 major program offices and more than 20 facilities. These reviews emphasized worker safety and verification that nonnuclear safety was adequately assessed by the cognizant line organizations for nuclear and nonnuclear facilities.

For the Dam Safety program, part of an interagency effort directed by the Federal Emergency Management Agency, the Office of Risk Analysis and Technology updated its inventory of Department dams. The office also

completed a baseline inspection of all Department dams to meet the requirements of the Dam Safety Act of 1986 and related Presidential memoranda.

In 1992 and 1993, the office evaluated 28 proposed nuclear safety orders to ensure their compatibility with nonnuclear standards and to verify that they adequately addressed worker safety issues. Existing departmental orders on the safety analysis and review systems and the ES&H Program were revised to improve their coverage of worker safety and health.

In conjunction with the Office of Nuclear Safety Policy, the office developed additional guidance on natural phenomena hazards mitigation design, which was issued in 1993. The natural phenomena hazards mitigation program provided general oversight and direction for departmentwide programs and ensured that the requirements of the Federal Earthquake Hazards Reduction Act of 1977 were met and that annual reports to the President and Congress were made. In 1992 and 1993, this program provided technical assistance to line programs and participated in technology transfer activities through national phenomena hazards mitigation conferences, interagency workshops, and Department programs that focused on saving lives, reducing property damage, and protecting the public and the environment.

Chemical Safety

The Chemical Safety Program was initiated in April 1992. The program's first major product was the *Task Group Report to the Assistant Secretary for Environment, Safety, and Health on Oversight of Chemical Safety at the Department of Energy*, DOE/EH-0282 (two volumes), in November 1992. This report summarized deficiencies identified in chemical safety across DOE and helped establish the long-range objectives of the program.

The Chemical Safety Program, in cooperation with the Office of Occupational Safety, also provided technical assistance to help line organizations comply with the February 1992 OSHA final rule (CFR 29 part 1910.119), "Process Safety Management of Highly Hazardous Chemicals" (the PSM Rule). The Office of Safety and Quality Assurance published two PSM Rule guidelines and developed and conducted four 3-day training courses on process safety management and process hazard analysis. In May 1993, the office conducted a HAZOP (hazards and operability) study on a DOE water chlorination process to demonstrate the use of a process hazards analysis technique to meet the requirements of the PSM Rule. The study was published as *Example Process Hazard Analysis of a Department of Energy Water Chlorination Process*, DOE/

EH-0340, in September 1993. This study was a cooperative effort among DOE, Westinghouse Hanford Company, and Battelle Laboratory staff members. Additionally, the office developed and issued a working draft guideline, "Decision-Making Methods for the Determination and Disposition of Action Items from Process Hazard Analyses Conducted on Department of Energy Facilities," as the third in a series of guidelines developed to help DOE facilities respond to the PSM Rule.

In February 1993, the office coordinated a workshop on chemical safety with leading U.S. chemical companies. Representatives from three commercial chemical companies discussed chemical safety policy and safety principles, including process safety management systems, safety culture, continuous safety improvement, and elimination of highly hazardous chemicals, with Headquarters staff and management and operating contractor representatives. The office developed "C-Rank," a method for identifying those DOE facilities that contribute most to chemical accident risk, enabling the office to concentrate technical assistance and oversight resources on those sites and facilities where they will do the most good. The office also published four issues of *Risk Management Quarterly*, a DOE newsletter on engineering risk management.

Environmental Restoration and Waste Management Cleanup Worker Initiative

The Office of Occupational Safety and Quality Assurance established a technical partnership with the Office of Environmental Restoration and Waste Management (EM), under which the Office of Occupational Safety and Quality Assurance will provide technical support on cleanup issues, identify and communicate lessons learned from hazardous waste cleanup and remediation outside the DOE complex, and resolve findings from the Office of Technical Assessment report. This report addressed the risks confronting the workers who will clean up radioactive and toxic wastes and restore and remediate environments at Department of Energy facilities. It also analyzed occupational health and safety issues from experiences at nuclear facilities and discussed how the lessons learned might be applied to the Department.

This joint effort will enhance the Department's ability to address worker safety and health issues associated with DOE cleanup operations. More than 10 outreach meetings were held for EH and EM managers and staff on DOE and non-DOE cleanup experiences, and 5 visits were made to DOE, EPA Superfund, and Nuclear Regulatory Commission-licensed sites. Both DOE and non-DOE safety and health documents and regulations, including those of in-

ternational agencies, were reviewed. The office also helped EM develop the worker safety and health strategy for the deactivation of the PUREX and UO₂ plants at the DOE Hanford site and supported EM in the development of a risk methodology for the ranking of the Department's surplus facilities.

Transportation and Packaging Safety

The Office of Risk Analysis and Technology, through its Transportation and Packaging Safety Division, is responsible for three primary functions: (1) certifying packages that the Department and its contractors use when transporting hazardous materials, including nuclear materials, over public roads and on Department sites; (2) performing independent safety oversight of the Department's packaging and transportation activities over highways, railways, and water; and (3) ensuring safety in the Department's aviation activities.

Packaging Certification

The packaging certification program ensures that the packages and containers used to transport radioactive materials and other hazardous materials will not present undue risk to life, property, and the environment. This assurance is accomplished through a comprehensive review and evaluation of safety analyses submitted to support the use of each package. In 1993, the office reviewed and issued certifications for 11 Type B packages, which are used to carry large quantities of highly hazardous radioactive materials. Under the Type A packaging testing program, one test was initiated to evaluate containers against regulatory requirements in 1993; five others were completed, and approvals were issued. (Type A packages are used to carry small quantities of low-hazard radioactive materials.)

To help departmental elements understand the complex requirements for Type B radioactive materials packages, the office is sponsoring the complete revision of the *Cask Designer's Guide*, which was last published in 1970. The guide provides information on designing packages for transport of large quantities of radioactive materials, including spent fuel; it will be used by the Department, other governmental agencies, the U.S. commercial sector, and entities outside of the United States. The guide is expected to be published in late 1994.

To ensure the quality of safety analyses submitted for review by package developers, the office offers several courses in packaging and engineering analysis. Twelve technical training courses were conducted in 1993. These

courses covered packaging welding criteria, quality assurance, gas generation, acceptance and qualification tests, and methods for reviewing safety analysis reports for packages.

In July 1993, the office offered a course entitled "Standardized Computer Analysis for Licensing Evaluation (SCALES)." The purpose of this course was to instruct users in the basics of a state-of-the-art computer code system that helps evaluate criticality safety, shielding, and heat-transfer performance related to nuclear facilities and packaging designs. Sixty-five people, including 13 international participants representing 8 countries, attended the course.

In the regulations area, the Office of Safety and Quality Assurance works closely with the U.S. Department of Transportation and the U.S. Nuclear Regulatory Commission on the revision of domestic and international packaging regulations. The office provided significant input into the development of the International Atomic Energy Agency's *Regulations for the Safe Transport of Radioactive Materials, Safety Series No. 6*, including chairing meetings and working groups and developing position papers that formed the basis for new international requirements.

Packaging and Transportation Safety

The Office of Risk Analysis and Technology's transportation and packaging safety assessment program conducts comprehensive transportation and packaging safety reviews of the line program offices within the Department facilities. Assessment areas include hazardous materials packaging, personnel training, and hazard communication. The office conducted three transportation and packaging assessments during 1993. In response to the findings from these reviews, a transportation and packaging safety technical assistance program has been developed and will be implemented in spring 1994. Assistance will consist of site visits to provide support to the operations offices, onsite training classes, and site-specific guidance documents to address identified problem areas. A quality assurance assessment program for packagings used to transport hazardous materials has also been developed. This program, to be implemented in early 1994, will include reviews of as-built packages, engineering drawings, packaging maintenance, and recordkeeping.

The office also completed a review of the congressionally mandated study of the safe transport of plutonium by sea. This document will provide information to Congress and the public on this highly visible activity.

Aviation Safety

The Office of Risk Analysis and Technology is also responsible for safety oversight of the Department's aviation operations. The Department operates approximately 40 aircraft, which are either owned or leased in lieu of ownership. The Department also operates two paved airports, two gravel airstrips, and multiple heliports and helipads. In addition to the aircraft owned or leased by the Department, aircraft are chartered on an as-needed basis.

To ensure that the Department safely operates its aviation equipment, the office conducts periodic assessments of field organizations to verify compliance with DOE orders and applicable Federal Aviation Regulations. In 1993, the office independently conducted five assessments and participated as an observer in four assessments conducted by the Office of Defense Programs.

In February 1993, after extensive negotiations with programmatic and operations offices, the office published a revised DOE Aviation Safety Order. Revisions to the order were substantial and encompassed areas of the aviation program that had not been addressed previously. The revised order establishes comprehensive, detailed guidance on the conduct of departmental aviation operations for the first time and incorporates applicable Federal Aviation Regulations and codifies their relationship to departmental aviation operations.

The office has also continued to implement the recommendations of the 1992 Aviation Task Group. In March 1993, the office sponsored the first annual Aviation Operations Policy Workshop. The workshop, which was hosted by the DOE Nevada Operations Office, brought together more than 80 individuals from the Department's aviation programs. The workshop covered a wide range of departmental aviation topics and included issue-specific working groups as well as presentations from Bell Helicopter and the General Services Administration.

The office made significant progress toward establishing the new Office of Aviation Operations Policy (OAOP) in 1993. A program plan for the new office has been developed, and the administrative requirements for the establishment of the new office have been satisfied. Two of the three approved staff positions in the new office have been filled, and aviation policy and property management initiatives were developed to accommodate the expanded aviation responsibilities. The expanded responsibilities include responding to Office of Management and Budget reporting requirements and assuming the obligations related to procuring aircraft for the Department.

The office is a resource that is readily available to Headquarters and operations office managers in need of aviation-related technical assistance. In 1993, the Office of Risk Analysis and Technology participated in a number of aviation-related technical support activities, both internal and external to the Department. At the request of the administrator of the Western Area Power Administration, extensive technical assistance was provided for the DOE aviation accident investigation of the December 1992, aircraft crash in Billings, Montana, that resulted in multiple fatalities.

In addition to internal assistance functions, the office participates in the activities of organizations outside the Department. For example, the office has become increasingly involved in the Interagency Committee on Aviation Policy. This committee includes representatives from all nonmilitary, executive branch Federal agencies that operate aircraft. A senior staff member is currently the chairperson of the Committee's Steering Group, which was established to conduct strategic and tactical planning and to direct the focus of the organization's activities. Another staff member is currently serving as the chairperson for the Committee's Aviation Safety Subcommittee. This subcommittee is tasked with creating and modifying aviation safety requirements that are codified in the General Services Administration regulations and are applicable to all Federal agencies.

HEALTH

Introduction

The Office of Health develops departmental policies and standards related to all aspects of radiation protection, industrial hygiene, and occupational medicine. It ensures their implementation through independent internal assessments and appraisals of line program and contractor management with respect to industrial hygiene programs. The office also develops standards and policies for occupational medical programs and ensures their implementation by line program and contractor occupational medical staff through independent field assessments.

The Office of Health collaborates with and provides support and assistance to the Office of Safety and Quality Assurance on matters of occupational safety that affect, relate to, are part of, or are affected by the Department's occupational health program. The office also provides direct technical support to line programs concerning ra-

diological protection, industrial hygiene, and occupational medicine.

Health Physics and Industrial Hygiene

The Office of Health Physics and Industrial Hygiene develops new or revised policies, standards, minimum requirements, and guidance for high-quality radiation protection and industrial hygiene programs at DOE facilities. The office performs industrial hygiene program assessments and appraisals in the field with the help of the Office of Safety and Quality Assurance. The office also responds to and follows up on operating incidents that involve hazardous substances or exposure of workers to excessive radiation to ensure prompt line response. The office supports line management in initiating immediate actions, and it uses lessons learned to identify generic issues on occupational health practice for future program consideration.

The Office of Health Physics and Industrial Hygiene also represents DOE on national and international radiological protection and industrial hygiene worker protection standards-setting bodies and acts as the liaison to other DOE programs to disseminate information as appropriate. The office also manages the DOE Laboratory Accreditation Program for personnel dosimetry (radiation measurement) programs; other accreditation programs are planned for the future. The office manages the health physics and industrial hygiene research programs at national laboratories that directly apply to DOE operations and to enhanced occupational health protection at DOE facilities, and it manages both the Health Physics and Industrial Hygiene Graduate Fellowship Programs, which includes conducting research at participating fellowship universities to support DOE research needs in occupational health.

Another role of the office is serving as manager of the DOE Marshall Islands Program. This entails setting policy, management operation, and program direction as well as providing logistical support necessary to conduct medical surveillance and care, radiological, and environmental monitoring programs mandated by the Compact of Free Association (Public Law 99-239). Finally, the office works with the local Spanish authority for Project Indalo, initiated in 1966 by the United States, in cooperation with the Spanish Government, to clean up a plutonium-contaminated area created by a collision at Palomares, Spain, of a U.S. Air Force KC-135 tanker and a B-52 bomber that

involved two nuclear weapons. An agreement between the governments of the United States and Spain, the Otero-Hall International Agreement, mandates that DOE provide continued support as needed.

Guidance and Policy Documentation

In 1992, the Office of Health Physics and Industrial Hygiene developed and issued the *DOE Radiological Control Manual* and the Core Standardized Training Materials Series. These documents provide radiological protection guidance that is both comprehensive and standardized for the entire DOE complex. The office developed the proposed rule relating to radiation protection for occupational workers (10 CFR Part 835). Comments received during the public comment period were resolved, and the rule was circulated for DOE concurrence in preparation for issuing a final rule in late 1993. The rule was signed by the Assistant Secretary for Environment, Safety and Health; approved by the Secretary; and subsequently published as a Final Rule in the *Federal Register* on December 14, 1993. In addition, the office helped develop radiological health and safety policy to be issued as a notice in 1993. This policy will serve as the Department's formal commitment to the "as-low-as-reasonably-achievable" (ALARA) process and excellence in radiological controls.

The office is planning to issue 12 implementation guides in the areas of internal dosimetry, radiation-generating devices, instrument calibration, posting and labeling for radiological control, and radiation protection training. These implementation guides, currently designed to support 10 CFR 835, were scheduled to be published and distributed throughout DOE in January 1994. The Office of Health Physics and Industrial Hygiene continued to publish "Health Watch" flyers that provide timely information on concerns and developments that are particularly important for enhancing the awareness and effectiveness of DOE's industrial hygiene community. It developed emergency response planning guides (in collaboration with private chemical companies and the American Industrial Hygiene Association).

In 1992 and 1993, the Office of Health Physics and Industrial Hygiene published or distributed the following documents:

1. *DOE Radiological Control Manual*
2. *Twenty-Second Annual Report: Radiation Exposures for DOE and DOE Contractor Employees—1989* (distributed in December 1992)

3. *Twenty-Third Annual Report: Radiation Exposures for DOE and DOE Contractor Employees—1990* (distributed in December 1993)
4. *Study of ALARA Programs—Status 1990*
5. *Study of ALARA Programs—Good Practice Documents*
6. *DOE Guidelines for the Selection of Chemical Protective Clothing—1991 Update—Performance, Availability, and Sources of Chemical Protective Clothing*
7. Title 10, part 835, *Code of Federal Regulations* (10 CFR 835), "Occupational Radiation Exposure," published in the *Federal Register* in December 1993
8. *Health Watch*: "New Regulations to Control the Spread of Bloodborne Diseases," "New Interim Final Regulation to Reduce Lead Exposure for Construction Workers," "Asbestos Control Programs—New Requirements for Inspectors and Other Personnel Involved in Asbestos Control Programs at the Department of Energy Owned or Leased Facilities," and "OSHA Removes Nonasbestos-form Minerals from Standards"

Education and Research

The Office of Health Physics and Industrial Hygiene organized and sponsored various meetings and workshops to improve communications among DOE officials and the management and operating contractors at DOE facilities and to identify and resolve programmatic and technical concerns related to worker protection. These included the ALARA Workshop, the DOE Health Physics Conference, and the DOE Industrial Hygiene Conference and extensive efforts in organizing a special session for DOE at both the annual Health Physics Society meeting and the American Industrial Hygiene Conference and Exposition.

The office interacted extensively with other entities in 1992 and 1993. For example, it actively participated in meetings of the Committee on Interagency Radiation Research and Policy Coordination panel and specific subpanels, including the Subpanel on Recommendations on Radiological Protection, the Subpanel on the Use of BEIR V and UNSCEAR 1988 in Risk Assessment, the Subpanel on Occupational Radiation Protection Research, and the Working Group on Naturally Occurring and Accelerator-Produced Radioactive Materials.

The Office of Health Physics and Industrial Hygiene helped operations offices in both Richland and Savannah River to deal with important worker protection problems.

In Richland, the office helped develop worker-exposure-monitoring strategies for the tank farms and site-specific, real-time health and safety plans for the tank farm restoration project. In Savannah River, the office helped investigate and correct a recurring problem of air-line respirator hose couplings coming apart during use.

The office managed a research grants program for national universities to promote research initiatives and education in the field of radiation protection. Twenty fellows are enrolled in each of the office's Health Physics Industrial Hygiene Graduate Fellowship Programs, which addresses the long-term problem of inadequate numbers of properly trained health physicists and industrial hygienists available to manage DOE's occupational health hazards. The office has field-tested a prototype of a real-time monitor for airborne beryllium to help control chronic beryllium disease and a heat stress monitor to telemeter (transmit via radio signals) to a supervisor a worker's vital signs. Both monitors are being readied for commercial development with private sector partners.

International Work

The Office of Health Physics and Industrial Hygiene was busy internationally in 1992 and 1993. As part of the Marshall Islands Program, the office assisted the Rongelap Local Government Council and the Republic of the Marshall Islands in developing a strategy for resettling the Rongelap people to Rongelap Atoll and to resolve questions about the atoll's habitability. The office also continued work with a National Academy of Sciences Scientific Peer Review Group that reviews protocols, procedures, models, and dose assessment methodologies necessary to properly characterize the radiological environment and potential exposure to local inhabitants on the Marshall Islands, with particular emphasis on Rongelap Atoll.

Assessments

In 1992 and 1993, the Office of Health Physics and Industrial Hygiene provided direct staff support for 11 Tiger Team and technical safety appraisal actions and 1 followup probe and 5 progress assessments, respectively. The staff served as team members and technical representatives of the Office of Health, validating the team's occupational health findings. The office also reviewed the contractor action plans for the progress assessments and accepted or provided comments on the proposed corrective actions. The office conducted one oversight assessment and four operational readiness reviews of facility

startups. The oversight assessments covered issue management, conduct of operations, and hazard assessment and control. In addition, the office provided direct staff support for an Occupational Safety and Health worker protection pilot program and helped with hazard communication. In 1992, the office conducted 8 technical assessments and 14 oversight assessments; 6 of the oversight assessments were operational readiness reviews or facility startups, and the other 8 were reviews of technical areas such as issue management, communicating chemical hazards to workers, and consequence assessment.

Epidemiology

The Office of Epidemiology investigates and communicates the actual and potential effects on human health from the development and use of new energy technologies, environmental restoration of weapons complex sites, weapons production and dismantlement, and other activities related to DOE. The office also develops and sponsors a systematic, scientifically oriented human health effects research program and disseminates health-related information to workers, the public, and other departmental elements.

Epidemiologic Surveillance Program

The Epidemiologic Surveillance Program monitors the health of the workforce at DOE sites to identify health hazards in the workplace. The program compiles and integrates information on the health experience of workers, determines the rates and risk of illness and injury among workers, and provides information to all stakeholders. Data are provided in response to questions from workers, physicians, and others about possible health effects. In 1993, the office expanded the Epidemiologic Surveillance Program to 10 DOE sites, with plans to increase to 13 sites in 1994.

Epidemiologic Studies

The Office of Epidemiology conducts DOE-managed descriptive epidemiologic studies at DOE facilities and nearby communities. These include descriptive studies on DOE contractors, hypothesis-generating studies related to the potential health effects of energy production and the use of new energy technologies, ecologic studies of offsite populations, quick-response investigations of suspected disease clusters, and others as needed. The office also spon-

sors a research program in analytic epidemiology, which is conducted under the auspices of the Department of Health and Human Services. The program comprises a number of studies on DOE contractors (under the management of the National Institute for Occupational Safety and Health) and several dose reconstruction and environmental epidemiologic studies of populations residing near DOE facilities (under the management of the Centers for Disease Control and Prevention).

Comprehensive Epidemiologic Data Resource

The office is also involved in developing and managing the Comprehensive Epidemiologic Data Resource (CEDR), which makes epidemiologic data available to the public. Sharing these data through CEDR supports the new spirit of openness in government and the DOE initiative to make environmental, safety, and health information available to all stakeholders. CEDR contains data on more than 420,000 workers employed at 1 or more of 50 DOE sites over a period of approximately 30 years. A CEDR catalog is available, and CEDR information can be accessed online either directly or through Internet using a gopher server.

State Health Agreement Program

The State Health Agreement program provides grants to state health departments (or other institutions identified by the state) of states that host DOE facilities. Each grant provides funds to conduct independent epidemiologic research or other community health surveillance activities to determine the potential adverse health effects of Department operations on people residing in neighboring communities. Local advisory panels selected by the grantees oversee the conduct of activities under these grants. As the Department shifts its principal focus toward dismantling existing nuclear weapons and environmental restoration of weapons research and production sites, this program will be expanded accordingly.

Publications and Liaison

The Office of Epidemiology maintains current and relevant epidemiologic and other scientific literature, including publications on methods development, epidemiology, and radiation research. The office also provides liaison with the National Tripartite Council, the Secretary of Energy Advisory Board, the Environment, Safety and Health Advisory Committee, the Committee for Inter-

agency Radiation Research Policy and Coordination, the National Academy of Sciences, and all site- and study-specific committees (which the office supports and helps establish). A strong program is maintained by involving university scientists through research grants or supported collaboration with DOE contractors, including the national laboratories. This expands the existing base of expertise and provides support for training and educating young scientists.

The office also develops reports and newsletters and routinely publishes the *Health Bulletin*, *Health Watch*, and *Health Hazard Alert*, which are distributed throughout the DOE complex. These publications present timely information on epidemiologic studies, new legislation, regulations, rules, orders, and other health-related issues of importance to the Department and contractor workers. The office also publishes and distributes a quarterly Office of Health newsletter containing more general information on programs and new initiatives regarding departmental health activities, and prepares and widely distributes annual reports of activities.

Occupational Medicine

The Office of Occupational Medicine provides oversight and establishes policy and guidance for DOE contractor occupational medical programs. The office conducts management reviews, assessments, and investigations of DOE contractor occupational medicine programs to ascertain their compliance with state, departmental, and Federal occupational health and medical policies, standards, and good practices. The Office of Occupational Medicine reviewed 30 DOE contractor occupational medical sites in both 1992 and 1993.

The office establishes and manages applied research programs on worker medical monitoring and sponsors preventive-medicine and health-maintenance health services research in various health fields, such as alcohol and drug abuse programs, wellness programs, and health counseling. It develops and maintains the capability to conduct rapid medical investigations and to analyze accident investigations involving trauma or loss of life for workers at DOE sites. The office also ensures the integration of contractor occupational medical programs within the contractors' management structure and professional liaison with local, county, state, and Federal emergency and disaster programs. As part of this mandate, the office is responsible for managing the DOE Radiation Emergency

Assistance Center/Training Site (REAC/TS) program in Oak Ridge.

The Office of Occupational Medicine continued to develop the DOE Medical Surveillance Program, a proactive, preventive occupational health monitoring system that will allow the DOE site occupational medical programs to identify possible physiological reactions to workplace substances before these substances actually cause disease or disability. This comprehensive program is designed to facilitate the monitoring of current DOE contractor employees, to help standardize the data collection process of medical information, and to provide DOE contractor medical departments with a tool for the early detection of negative health trends within the workforce. Four pilot sites have been initially selected to develop and implement this system. The program gained momentum with the passage of the National Defense Authorization Act for Fiscal Year 1993 (Public Law 102-484). Section 3162 of the act mandates that DOE establish a comprehensive medical surveillance program for DOE contractors and subcontractors who have been exposed to significant hazards while working at DOE sites. Milestones for 1993 include the signing of an interagency agreement with the Department of Veterans Affairs to provide support in the area of medical informatics, the development of the minimum data set for use across all sites, the drafting of a memorandum of understanding with the Department of Health and Human Services, and the consolidation of DOE medical surveillance activities, such as the DOE Beryllium Program, into the office.

The office continues to provide medical oversight for the DOE Marshall Islands Medical Program. The goal of this effort is to provide quality medical monitoring to the exposed populations.

The Office of Occupational Medicine also provides technical, medical, and behavioral science support for DOE legal staff, other Headquarters elements, and operations office management. It supports workshops and seminars on applying new techniques that address occupational medicine and psychology.

The office sponsored several national and international medical conferences for operations office personnel and site occupational medical program personnel. Subjects included the Americans with Disabilities Act, substance abuse, use of biomarkers for worker health monitoring, and computer-assisted systems. One of these conferences focused on the medical computing capabilities of the contractor occupational medical programs. In 1993, the office drafted or edited in preparation for publication six orders or guidelines relating to medical occupational standards.

NUCLEAR SAFETY

The Office of Nuclear Safety (ONS) was established in February 1990 to provide effective independent oversight of nuclear safety across the DOE complex; ensure the Secretary of Energy and, in turn, Congress and the public that DOE workers, the public, and the environment are receiving the highest level of health and safety protection reasonably achievable from DOE nuclear operations; and to establish a new nuclear safety culture. In June 1993, the Secretary realigned the functions of the Department and placed ONS under the Assistant Secretary for Environment, Safety and Health. Under its charter, ONS monitors and audits all aspects of nuclear safety through inspections, assessments, and investigations to identify circumstances indicative of deteriorating or inadequate nuclear safety performance. ONS also enforces the Department's policies and programs associated with the civil and criminal penalty authority of the Price-Anderson Amendments Act of 1988 and oversees the Department's Radiological Protection Program.

In light of the Department's changing mission and the large number of nuclear facilities (2,700) for which ONS has safety oversight responsibilities, all ONS staff were called on to participate in a comprehensive strategic planning exercise. This exercise was designed to develop methods to enable ONS to monitor line organizations more effectively, help them improve nuclear safety performance, and institute a nuclear safety culture within the DOE nuclear community. As a result, six cohesive goals were developed, and each goal was translated into a corresponding program composed of projects specifically tailored to meet the program goal. The ONS program plan has been implemented, and currently, activities are defined and resources are allocated on the basis of these programs and supporting projects, rather than along organizational lines.

Oversight of Nuclear Standards

The goal of this program is to provide assistance in developing and implementing a coherent set of nuclear safety rules, orders, standards, and guides. Projects performed include reviewing proposed standards, with a focus on improving the process as well as providing technical comments on the standards, and evaluating the implementation of newly published rules, orders, standards, and guides. Projects also involved participation in standards-related activities such as the development of guidelines for safety

analysis reports (SARs), environmental impact statements (EISs), and environmental assessments (EAs); the development of worker safety under radiological accident conditions; the development of principles for performing decontamination and decommissioning activities; the development of a reliability data base for equipment and systems; and the development of a radiological release fraction standard.

Oversight of Line Ownership and Accountability for Nuclear Safety

The goal of this program is to substantially improve line organizations' ownership of and accountability for nuclear safety. Projects included evaluation of functional programs such as decontamination and decommissioning, procedures development and use, startup and restart programs, occurrence reporting and lessons learned, and criticality safety. Radiological evaluations were performed by small teams to assess the implementation of chapter 1, parts 2 and 3, of the new *DOE Radiological Control Manual*. These evaluations aimed to significantly improve management ownership of radiological programs, enhance radiological work practices, and ensure worker protection. Assessments were also conducted to determine age-related degradation of DOE facility structures, systems, and components. In addition, Office of Nuclear Safety assessors were stationed onsite at six of the larger DOE sites, where they oversaw daily facility operations.

Communication and Cooperation

The goal of this program is to engender effective communication, cooperation, and integration of nuclear safety information among and within DOE and contractor organizations, particularly the sharing of lessons learned. Several projects were designed to evaluate and improve existing systems used by Headquarters, field offices, and contractor organizations to transmit safety information that directly impacts the safe operation of DOE nuclear facilities. Projects also focused on DOE activities to identify networks, pathways, and forums for exchanging safety information throughout the DOE nuclear community. These efforts were tailored to improve the dissemination and communication of safety information and also to im-

prove Headquarter's ability to clearly communicate guidance and expectations by eliminating inefficient and unproductive processes that operate at cross purposes and hinder organizational objectives.

Compliance with Nuclear Safety Requirements

The goal of this program is to enlist line organizations to pursue and achieve voluntary and effective compliance with DOE's nuclear safety rules. Projects included the development of a final DOE enforcement rule and policy (10 CFR 820), which was published on August 17, 1993. Other projects included rule implementation and compliance programs to provide contractors further guidance on how rules will be applied and implemented at nuclear facilities. The Office of Nuclear Safety Enforcement conducted workshops to underscore the benefits of voluntary compliance and to inform DOE and contractor personnel of the details of the enforcement process. A noncompliance tracking system was developed to monitor contractor performance and to help identify generic and facility-specific problems. In addition, a fair and equitable program was developed to investigate infractions of the safety requirements and to initiate enforcement actions if there are violations of DOE rules.

Nuclear Safety Operations

The goal of this program is to increase the effective and efficient management of ONS resources by conducting training, including initial qualification training, requisite training for access to DOE facilities and sites, training on specific processes and hazards of facilities, and training on safety standards and assessment techniques. In addition, internal procedures were developed to ensure ONS projects are fully coordinated, meet common standards, and are conducted according to applicable DOE orders and ONS policies. Management information systems were evaluated to promote more effective internal communication, coordination, and cooperation and to improve planning, scheduling, support services, and contract management. Performance measures were developed, and periodic self-evaluations will be conducted to ensure peak proficiency in all aspects of ONS operations.

Special Secretarial Nuclear Safety Initiatives

Several special Secretarial assignments have been delegated to ONS, one of which is to represent the Department on the Interagency Nuclear Safety Review Panel. This panel, which consists of members from DOE, the National Aeronautics and Space Administration, and the Department of Defense, provides the President with an independent assessment of the risks associated with launching space nuclear power systems. Other special assignments include safety oversight of three Department of Defense reactors that are not under the cognizance of Naval Reactors and the DOE gaseous diffusion plants that are being transferred to a government corporation regulated by the Nuclear Regulatory Commission. ONS is also performing vulnerability assessments of DOE spent-fuel storage facilities and of plutonium and highly enriched uranium storage and disposition issues at the request of the Secretary.

SECURITY EVALUATIONS

The Office of the Deputy Assistant Secretary for Security Evaluations, as the DOE focal point for all safeguards and security independent oversight activities, is responsible for independently inspecting and evaluating the safeguards and security posture of the Department of Energy. Security Evaluations reports the results of its oversight activities to the Secretary through the Assistant Secretary for Environment, Safety and Health. Security Evaluations also maintains the North Atlantic Treaty Organization (NATO) subregistry for the Department and is responsible for inspecting the Department's NATO control points and accompanying the Department of Defense survey teams to NATO commands to ensure that data are properly protected.

Security Evaluations oversight activities are independent of the Department of Energy's safeguards and security community. Line management responsibility for safeguards and security activities is exercised through cognizant secretarial offices while policy is executed through the Office of Nonproliferation and National Security (formerly the Office of Intelligence and National Security). Security Evaluations is organizationally isolated from safeguards and security line management and policy formulation and therefore can analyze departmentwide safeguards and security indicators and trends from a broad, departmental viewpoint, thus providing a unique perfor-

mance measurement of safeguards and security effectiveness.

To gather the data required to support its independent evaluation, Security Evaluations conducts a number of activities, including comprehensive inspections of major departmental facilities; short-notice, limited-scope safeguards and security readiness reviews of departmental facilities; and assessments of selected issues using data gathered from across the Department by specially constituted study teams. To measure programmatic status, Security Evaluations formulates programmatic metrics that reflect current status and multiyear trends. Information collected in longstanding safeguards and security topic areas, such as physical security systems and material control and accountability, is quantified to support these metric determinations.

In October 1993, Security Evaluations published its annual report of the status of safeguards and security, which independently assesses both the status of these program elements (based on information collected during 1993) as well as multiyear trends based on information collected in previous years. The report identified a number of areas where the Department could improve its safeguards and security program and a number of areas where more extensive management attention could reduce costs. Results are reported under three overall groupings: safeguards and security management and oversight, protection of special nuclear material, and protection of information.

Security Evaluations also conducted a technology assessment delineating available and emerging state-of-the-art safeguards and security technologies, the objective of which was to help managers make informed decisions regarding technological options available. The assessment briefly describes selected state-of-the-art technologies, discusses possible applications to several broad areas of need within the Department, and lists points of contact for additional, more detailed technical information. Additional special studies included the following topics: Technical Security Countermeasures Program, Special Nuclear Material Inventory Verification/Confirmation Program, Personnel Clearance Program, and Security Helicopter Operations.

In 1993, Security Evaluations undertook a number of initiatives to improve the quality of its efforts, including extensive efforts to enhance and update the Inspectors Guides that establish a basis for standardizing techniques and procedures for inspecting oversight topic areas. The initiative with the greatest potential, however, is a training and certification program for Security Evaluations inspectors. This certification process, formulated by acknowledged experts in inspection techniques and meth-

ods who have extensive experience in inspecting departmental facilities, provides a needed standardization within inspection activities. This standardization, in turn, will enhance detailed analysis of safeguards and security issues. The improved data and more detailed analysis will identify additional opportunities for improving the Department's safeguards and security posture that can be carried out at reduced cost. These initiatives also have much to offer other disciplines within the Office of Environment, Safety and Health—in particular, worker health and safety.

SPECIAL PROJECTS

The Office of Special Projects conducts projects that cross-cut individual EH offices. These projects include developing and integrating crosscutting policy and technical issues, developing and managing an information management and analysis program, integrating EH concerns into departmental planning processes, and managing and conducting the EH Tiger Team and Progress Assessment programs. The office also develops and conducts workshops to instruct Department personnel on performing assessments and trend analyses, preparing action plans, and developing self-assessment programs.

One major accomplishment in 1992 was the completion of the EH Tiger Team Program. In July 1992, the last of the 35 Tiger Team assessments at the major DOE operating facilities was performed. These assessments have provided the Department with an accurate, comprehensive baseline of environmental, safety, and health (ES&H) compliance information on which to make informed operational decisions. Such information served to enhance the confidence of the public in the Department's ability to manage the DOE complex in a responsible manner. The Office of Special Projects summarized the assessment results and provided them to all DOE elements to help identify and correct problems. The summaries included trends in and root causes of systemic weaknesses and a summary of all noteworthy practices.

The office also oversaw the preparation of corrective action plans at the 35 facilities. These action plans provide the basis for the correction of deficiencies and the effective management of ES&H programs into the next century. As of December 31, 1992, 30 of the 35 action plans had been approved for implementation; 3 action plans were approved in 1993.

As part of the Department's continuing effort to institutionalize line management accountability and the self-assessment process and to evaluate actions taken in re-

sponse to Tiger Team findings, the Office of Special Projects performs small, focused ES&H progress assessments. The purpose of the progress assessments is to provide Department senior management with concise, independent information on the following:

1. Change in culture and attitude related to ES&H activities
2. Progress and effectiveness of the ES&H corrective actions resulting from previous Tiger Team assessments
3. Adequacy and effectiveness of the ES&H self-assessment programs of the Department's line organizations and the site management and operating contractors
4. Effectiveness of departmental and contractor management structures, resources, and systems in addressing ES&H problems and undertaking new initiatives

The pilot assessments for this new program were those performed at the Fernald Environmental Management Project and Y-12 Plant. The full implementation of the Progress Assessment Program began in 1992. In 1992, assessments were conducted at four sites—the Hanford Reservation, the Nevada Test Site, the Mound Plant, and the Lawrence Livermore National Laboratory.

In 1993, seven progress assessments were conducted at the Brookhaven National Laboratory, Savannah River Site, Pantex Plant, Rocky Flats Plant, Morgantown Energy Technology Center, Idaho National Engineering Laboratory, and Argonne National Laboratory. The Office of Special Projects summarized the results and provided them to all departmental elements.

In 1993, the office developed an Environment, Safety and Health Facility Profile Information Management System to more effectively plan and conduct future office oversight activities and to extract trends from assessment information. This system, which contains information on the 35 major DOE sites, such as the Tiger Team assessments and their associated action plans, progress assessments, environmental audits, institutional plans, National Environmental Policy Act documents, and Federal facility compliance agreements, can be used to identify issues, potential problem areas or facilities, and technical or management areas for assessment and to facilitate root-cause analysis and disseminate lessons-learned information departmentwide.

The Office of Special Projects has represented EH on the ad hoc work group set up to respond to the Defense Nuclear Facilities Safety Board's Recommendation 93-3,

which deals with improving the technical capabilities of personnel, including personnel in the area of environment, safety, and health. The Department of Energy response is broad-based and addresses technical capabilities across the spectrum of technical activity rather than solely the nuclear-related technology. The Defense Nuclear Facilities Safety Board accepted the ad hoc task group's response without modification. In 1993, the office also represented EH on the National Performance Review Team and on the Secretary's Quality Council.

The National Performance Review Team evaluated proposals to reduce barriers and unnecessary regulations, policies, and procedures and thereby make DOE more efficient and responsive to missions, improve its services, and reduce costs. The purpose of the Quality Council,

composed of 28 Federal as well as contractor employees from the various DOE organizations, is to design the approach, establish the conceptual framework, and become a driving force for the implementation of the DOE quality initiative.

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CHAPTER 20

POLICY, PLANNING, AND PROGRAM EVALUATION

NATIONAL ENERGY POLICY IMPLEMENTATION

The Energy Policy Act of 1992 (EPACT), signed into law on October 24, 1993, is a basis for the development and implementation of current and future energy policy in the United States. The 30 titles in the act address a comprehensive set of policies and actions that will affect the way this country produces and consumes energy well into the 21st century. The Department of Energy made substantial progress in implementing the provisions of the act during 1993. The Administration will continue to implement the act's provisions, which will improve energy efficiency, enhance energy security, reduce energy-related environmental effects, and encourage long-term economic growth.

The Department is undertaking a comprehensive strategic planning effort to ensure that budget requests reflect Administration energy policies. This departmentwide process is the cornerstone of integrated energy policy implementation and is a topic of the next section of this chapter.

The Department of Energy 1994 budget request reflected the Administration's goal of balancing the Nation's energy and economic requirements with protection of the environment. In line with post-Cold War exigencies, the Department began a careful restructuring of its national defense responsibilities. It also worked to fulfill the President's commitment to increase investment in science and technology development and transfer.

President Clinton's report, *A Vision of Change for America*, which was presented to Congress on February 17, 1993, stated that "Without thoughtful energy policies,

our nation will remain dependent on foreign oil and special interests. The Administration will launch initiatives to develop new, clean, renewable energy sources that cost less and preserve the environment. We will also encourage energy efficiency and conservation to lower the energy bill for middle-class Americans, and lessen our vulnerability to events outside our control."

The President's plan and the Department's policy implementation have three key elements: economic stimulus to create new jobs and lay the foundation for long-term economic growth; long-term public investments in energy technologies to increase the efficiency and productivity of U.S. citizens and businesses; and a serious, fair, and balanced deficit-reduction plan to stop the Government from draining the private investments that generate jobs and increase incomes.

STRATEGIC PLANNING AND PROGRAM EVALUATION

The Energy Policy Act of 1992, the end of the Cold War, the Administration's goal of redressing the imbalance among the Nation's energy and economic requirements and protection of the environment, and severe budget constraints were all major factors that enhanced the importance of the Department's strategic planning, program evaluation, and budget allocation processes. The Department's first opportunity to address these factors was in the complete review and reformulation of the 1994 budget request that was submitted to Congress in April 1993.

This budget represented the beginning of a new comprehensive process for rethinking the Department's fundamental responsibilities and how those responsibilities are carried out.

In mid-1993, development of a departmentwide strategic plan began. In the past, many DOE offices developed their own individual strategic plans, but these plans were not integrated into a departmentwide plan that adequately reflected the priorities and intentions of the Secretary. Because of their diversity, past strategic plans were unable to identify and address integrated, near-term objectives necessary for progress toward longer-term goals.

The Secretary determined that the Department would develop a top-down, departmentwide strategic plan that should address, at a minimum, the following five critical success factors that affect the ability of the Department to meet its mission-related goals and objectives:

1. Human resources
2. Management practices
3. Environment, safety, and health
4. Communications and trust
5. Business priorities

To clearly delineate the Department's goals, objectives, and strategies, the Secretary established a strategic, cross-cutting planning team for each of the critical success factors and the five core "product lines." These crosscutting teams were made up of elements throughout the Department. These product lines were industrial competitiveness, energy resources, science and technology, environmental quality, and national security. The Office of Policy, Planning, and Program Evaluation began to integrate the results developed by the strategic planning teams into a DOE strategic plan, which was scheduled to be available in early 1994. The plan will include the Department's mission statement, core values, vision, goals, strategies, and success indicators. The strategic plan will be used to drive the budgeting process, that is, any reprogramming needs for fiscal year (FY) 1994, the FY 1995 congressional budget debate, and the development of the FY 1996 budget.

Performance measurement was a critical component of the planning process and will be documented in both plans and budgets. The inclusion of performance measures was essential to program evaluation, the allocation of funds to support the Department's priorities, and the continuous improvement of the products and services that are provided by DOE to the Nation.

ECONOMIC AND ENVIRONMENTAL POLICY

Energy Efficiency and Alternative Fuels

Throughout 1992 and 1993, the Office of Policy, Planning, and Program Evaluation continued its analyses of opportunities for accelerating the introduction of alternative fuels in the transportation sector and increasing energy efficiency in all sectors of the economy. Fulfilling requirements for analyses contained in the Energy Policy Act of 1992 (EPACT) and the Alternative Motor Fuels Act commanded a major portion of the office's resources in these areas. The office also analyzed overall trends in domestic energy efficiency, initiated comparative assessments of projected efficiency trends, and analyzed the costs of oil conservation measures.

The Office of Policy, Planning, and Program Evaluation played a substantial role in the development, review, and initial implementation of those provisions of EPACT directed at improving energy efficiency in all sectors.

The office examined trends in the retrofit of residential buildings. In the industrial sector, the office examined the effects of voluntary efficiency targets and reporting requirements. The office also investigated policy options for improving the efficiency of motors and for stimulating stock turnover and investment in the industrial sector. The office also estimated energy savings and consumer reaction to potential programs in the transportation sector, including modified corporate average fuel economy standards, feebates, pay-at-the-pump auto insurance, and fuel taxes.

The Office of Policy, Planning, and Program Evaluation analyzed the feasibility of replacing gasoline with alternative fuels in personal and fleet vehicles and investigated different methods of promoting the use of alternative-fuel vehicles. The office included estimates of supply and demand of various fuels in these analyses. In addition, the office examined alternatives to transportation, such as telecommuting.

The Office of Policy, Planning, and Program Evaluation measured the effects of the Clean Air Act Amendments of 1990, including costs to refineries and consumers of the Environmental Protection Agency's (EPA's) reformulated gasoline regulations and certification models.

Concerning international issues, the office analyzed how energy efficiency improvements could be stimulated in

developing countries and cosponsored the Asian Efficiency Conference. The office will also cosponsor the International Energy Agency's Industrial Efficiency Workshop in spring 1994.

Economic Analysis and Competition

Because energy policy and technology options are often interrelated, the combined impact of a policy package often diverges significantly from the sum of the impacts of its individual components. For example, end-use efficiency standards and voluntary efficiency programs have partially overlapping effects. However, these demand-side programs have a synergistic interaction with efficiency research and development that raises the effectiveness of the latter above its stand-alone level. There are similar overlaps and synergies on the supply side of the energy sector, as well as interactions between demand- and supply-side policies because individual policies change both the prices of energy commodities and capacity requirements. Credible analysis of major energy policies must take account of these complex interrelationships.

Final action toward enactment of EPACT and important energy-related initiatives in 1993, including the energy tax component of the Administration's deficit reduction package and the President's Earth Day commitment to return U.S. emissions of greenhouse gases to their 1990 levels by the year 2000, made extensive use of the integrated analysis capabilities of the Office of Policy, Planning, and Program Evaluation.

Before the release of the Administration's economic package, the office worked in close collaboration with the White House, the Treasury Department, and EPA to analyze alternative energy tax proposals. After the release of the President's budget, the office briefed key stakeholders representing industry, environmental groups, and the public at large on the outline of the Administration tax proposal and worked with them to identify and address critical concerns as the detailed proposal was developed. Before and during congressional action on the package, the office provided timely quantitative information to members and staff regarding impacts of the Administration proposal and alternative proposals that were developed during the legislative process. The office also worked with the National Association of State Energy Officers and others to develop methodologies for measuring the direct and indirect cost to consumers of energy taxes.

The Integrated Dynamic Energy Analysis Simulation Model, an updated and improved successor to the FOS-SIL2 Model, was the primary tool used for modeling the energy sector implications of alternative energy tax proposals. The Integrated Dynamic Energy Analysis Simulation Model uses both an economic paradigm and detailed engineering relationships to estimate the demand for energy-related services and the supply and price of fuels. Examples of information developed during the discussion of energy taxes include projected impacts on production, consumption, import levels, and prices, all broken down by fuel type, as well as projected greenhouse gas emissions and direct and indirect costs to households.

The Office of Policy, Planning, and Program Evaluation continues to play a major role in providing analysis in support of the President's Earth Day commitment to return U.S. greenhouse gas emissions to their 1990 levels by 2000 using cost-effective actions that tap the creativity and ingenuity of the American people. These ongoing efforts involve extensive interagency collaboration and interaction with outside policy analysts whose input to the development of the U.S. greenhouse gas mitigation plan was actively solicited through the White House Conference on Global Climate Change.

DOE uses the Integrated Dynamic Energy Analysis Simulation Model as a primary tool for integrated analysis of mitigation options in the energy sector. The Office of Policy, Planning, and Program Evaluation presented Integrated Dynamic Energy Analysis Simulation Model analysis results to the plenary session of the White House Conference on Global Climate Change. In addition to providing integrated modeling analysis, the Office of Policy, Planning, and Program Evaluation collaborates with other agencies to review the costs, investment requirements, and projected greenhouse gas emissions reduction impacts of individual options.

While its major focus was on the analyses described above, the Office of Policy, Planning, and Program Evaluation pursued initial steps towards preparation of the Least-Cost Energy Strategy required in the National Energy Policy Plan and continued a review of the use of contingent valuation methods. Contingent valuation methods, which are increasingly used to estimate nonuse values, play a large role in issues affecting the Department, including groundwater cleanup at DOE facilities, visibility effects of powerplant emissions, oil spills, and the Endangered Species Act. The office also continued to improve the benefit from interaction with outside experts, most notably through its participation in Working Group III (Economics) of the Intergovernmental Panel on Cli-

mate Change and the Energy Modeling Forum review of the potential for increased energy efficiency.

Environmental Analysis

The Office of Policy, Planning, and Program Evaluation continued to participate actively in interagency, national, and international energy and environmental activities. Some of its interagency and international efforts in 1992 follow:

1. Establishing an interagency project to assist developing and transitioning countries in establishing their greenhouse gas inventories and in their efforts to mitigate global climate change
2. Serving on the U.S. delegation that negotiated more stringent measures to control the production and trading of ozone-depleting substances under the Montreal Protocol and the Framework Convention on Climate Change that was signed by more than 150 countries at the June 1992 Earth Summit.
3. Participating in the interagency planning for an international conference on the technical issues associated with biodiversity, and participating in the development of U.S. policy on an International Biodiversity Strategy
4. Helping develop the global climate change mitigation plan requested by the President in his Earth Day address
5. Representing the Department in an interagency process to develop the Administration's Clean Water Initiative

The office also participated in the Interagency Working Group for the Pollution Prevention and Control Group of the Organization for Economic Cooperation and Development by reviewing that organization's environmental research, activities, and reports.

In addition, the Office of Policy, Planning, and Program Evaluation was involved in United Nations-based environmental research and negotiations. Examples are participation on the Commission on Sustainable Development, the Intergovernmental Panel on Climate Change, and the Intergovernmental Negotiating Committee, which is charged with facilitating effective and early implementation of the United Nations Framework Convention on Climate Change.

An example of the office taking the lead in environmental analysis is the Mexico City Air Pollution Research Initiative. This study analyzed the origins of Mexico City's air pollution, compared several mitigation options, advanced the state of the art of air pollution measurement, and transferred the analytical capability underlying the study to Mexican officials. The office also participated in creating the draft report entitled "Energy Infrastructure of the United States and Projected Siting Needs: Issues and Options." This will be followed by a siting workshop to coordinate siting activities of states and tribal officials.

The office took the lead in coordinating the Department's response to proposed environmental legislation and regulation affecting energy supply and demand. Examples include commenting on and organizing responses to the proposed economic incentive program guidelines for state plans to achieve air quality standards, to EPA's approach to rethinking the urban ozone problem as required by the Clean Air Act, and to an EPA issue paper on the Basel Convention implementing legislation. The office has also undertaken the initial planning and first public outreach activities related to the rulemaking for the voluntary reporting program guidelines of section 1605(b) of EPACT.

The Office of Policy, Planning, and Program Evaluation remained integrally involved in commenting on environmental and natural resource related legislative and regulatory proposals. This is done by participating in or leading work groups that address the energy and environmental issues of topics such as the Hazardous Waste Identification Rule; the reauthorization of the Clean Water and Safe Drinking Water Acts; and the Comprehensive Environmental Response, Compensation, and Liability Act.

The office often sponsors studies as part of this work group participation and to adequately comment on proposed legislation and regulation. Some of these studies have investigated the impact on the energy industry of the potential loss of the 316(a) Clean Water Act variance, niche markets for alternative-fuel vehicles, and environmental and energy issues related to coal remining.

SCIENCE AND TECHNOLOGY POLICY

During 1993, the Deputy Assistant Secretary for Technology Cooperation, supported by the Office of Technology Policy, was responsible for formulating and recommending policies for the Department's overall tech-

nology development, deployment, and cooperation programs and for related research and development activities. The scope of the mission, based in part on the Administration's technology policy statements presented in *Technology for America's Economic Growth: A New Direction to Build Economic Strength*, dated February 22, 1993, included the analysis of the Department's technology plans, policies, options, and guidance; the analysis of technical, environmental, economic, financial, tax, trade, and institutional factors affecting the use of the Department's portfolio of technologies; and the development of technology cooperation and technology transfer policy.

Technology Transfer

During 1993, the Department continued to integrate technology transfer into its overall mission and into the activities of the program offices, national laboratories, and facilities. The ever-increasing emphasis on domestic and international technology transfer as a major departmental mission continued to strengthen the Department's overall technology transfer program. DOE promoted partnerships between industry, academia, and state and local governments to improve U.S. industrial competitiveness in the global marketplace.

Through the Technology Transfer Committee, the Office of Technology Cooperation addressed departmentwide technology transfer management and policy issues and participated in the development of a system of technology transfer performance measurements and a modular cooperative research and development agreement intended to reduce overall processing time.

The most significant joint effort of the Technology Transfer Committee, to which the Office of Technology Policy contributed, was the development of the Department's draft technology transfer strategic plan, entitled "Partnerships for Global Competitiveness." This effort resulted in the first crosscutting strategic plan encompassing all departmental technology transfer activities; outlined a series of key goals and initiatives; and defined the mission of the Department to be "the recognized leader and partner with industry in developing and transferring technology to enhance economic performance."

An important objective of the Department's technology transfer program was to facilitate and expand U.S. industry access to international markets. One major pro-

gram led by the Office of International Technology Cooperation was the Assisting Deployment of Energy Practices and Technologies (ADEPT) Program. ADEPT utilizes the expertise of private interests and the national laboratories to help developing countries and the Newly Independent States to develop policy-making capabilities for the wise selection of energy technologies and practices, and to create sound environmental policies within their energy sectors. The Department committed \$1.5 million in 1993 to the ADEPT Program. In addition, the Office of Policy, Planning, and Program Evaluation played a major role in the Trade Promotion Coordinating Committee chaired by the Department of Commerce. The Export Enhancement Act of 1992 established this committee to coordinate international technology transfer, export promotion, and finance activities of the U.S. Government.

As part of the requirements of EPACT, the Office of International Technology Cooperation led the effort to coordinate a memorandum of understanding, signed on July 14, 1993, between the Department and the Agency for International Development (AID) to establish three innovative technology transfer programs covering innovative renewable energy (section 1211), innovative clean coal (section 1332), and innovative environmental technologies (section 1608). The umbrella agreement allowed the responsible departmental program offices, the Office of Fossil Energy and the Office of Energy Efficiency and Renewable Energy, to establish interagency agreements with AID to develop and implement these programs.

Technology Policy

In 1993, the Deputy Assistant Secretary for Technology Cooperation and the Office of Technology Policy focused on the following activities:

1. Developing the framework for a comprehensive plan to implement and amplify the President's Technology Plan
2. Contributing to the technology policy sections of intra-agency reports to Congress required under EPACT
3. Contributing to interagency technology policy initiatives
4. Assessing technical policy issues related to the preparation and review of the Department's technology budget

The goal of the Department's technology policy initiatives, begun in 1993, was to develop an implementation framework for the Administration's technology strategy, which called for the following:

1. Establishing new criteria for organizing and directing the Department's civilian-related technology development programs to focus on economic growth and high-skill jobs
2. Accelerating the development of technologies to increase productivity and reduce harm to the environment.
3. Forging closer ties between Federal research and development programs and the needs of U.S. business through cost-shared research
4. Forging closer working relationships among industry; Federal, state, and local governments; and academia
5. Strengthening interagency coordination of Federal science and technology programs and policies
6. Ensuring the strength of Federal basic science and engineering research

In 1993, the Office of Technology Policy, in conjunction with other program offices, supported the Administration's technology strategy through the following technology policy activities:

1. Development of an interagency report entitled "Environmental Technologies Exports: A Strategic Framework for U.S. Leadership," led by the Department of Commerce and including DOE, the Environmental Protection Agency (EPA), the Export-Import Bank, the U.S. Agency for International Development, and the Overseas Private Investment Corporation
2. EPACT Section 2201—Development of a draft 5-Year Program Plan for the Advanced Materials Initiative in conjunction with other DOE program offices
3. EPACT Section 2202—Development of a draft 5-Year Program Plan for the Advanced Manufacturing Technologies Initiative in conjunction with other DOE program offices
4. EPACT Section 2205—Development of a 5-Year Program Plan for the Integration of Basic Energy Research Programs with other DOE Energy Programs issued on September 30, 1993
5. EPACT Section 2302—Development of a draft Management Plan for Energy Research, Develop-

ment, Demonstration, and Commercial Application of Technologies, including an Energy Technology Inventory and Status Report in conjunction with other program offices

6. Preparation of energy technologies data sheets on 26 energy technologies in response to an inquiry from Senator J. Bennett Johnston, Chairman of the Senate Committee on Energy and Natural Resources
7. Budget analysis and review of departmental programs

EXPORT ASSISTANCE

The Office of Export Assistance (OEA) manages and coordinates export assistance programs at the Department of Energy by working with departmental program offices and laboratories, and with appropriate U.S. Government agencies to increase the Nation's export of energy-related services, equipment, and technology. The office helps U.S. companies, as appropriate, to identify overseas opportunities and discriminatory trade barriers, and it organizes conferences, both at home and overseas, to promote U.S. energy technologies. In addition, the office reviews U.S. laws and regulations which may restrict trade.

Working through the interagency Trade Promotion Coordinating Committee, OEA focuses on special projects that promote U.S. industry and U.S. technology. By providing expertise on energy-related trade, the office works with the Departments of Commerce and of State, the Agency for International Development, the Trade and Development Agency, the Environmental Protection Agency, and the Office of the United States Trade Representative to implement their policy and programs.

Purpose and Mission

OEA is responsible for implementing policies and programs aimed at enhancing the export of U.S. energy goods, services, equipment, and technologies. It serves as the Department's focal point for energy firms seeking Federal assistance to overcome barriers in overseas markets. OEA works with both private-sector companies and appropriate agencies to ensure a coordinated and unified effort in pursuing export opportunities. The purposes of these policies and programs are to provide information on leading-edge U.S. energy technologies; collect information on

foreign energy development plans; provide information on U.S. regulatory and environmental policies affecting energy development; support U.S. firms' commercial interests abroad; and provide an opportunity for the U.S. energy industry to demonstrate its leading role worldwide in developing and deploying environmentally sound energy equipment and services. These activities support the mission and goals of the Department by encouraging actions that contribute to industry competitiveness and United States Government energy efficiency and environmental objectives.

Section 201 of the Export Enhancement Act of 1992 requires the President to establish the Trade Promotion Coordinating Committee, the purpose of which is to provide a framework to develop a strategic plan and coordinate the Government's export promotion activities. As a representative of the Department on the Trade Promotion Coordinating Committee, OEA works to ensure that priority is placed on energy industries, continues to introduce trade promotion initiatives for energy industries, and develops interagency consensus for support.

To showcase U.S. energy technologies and in cooperation with the Trade and Development Agency, the U.S. Agency for International Development, the Department of the Interior, Exim Bank, and the Department of Commerce, DOE has organized a series of seminars and conferences for foreign consumers of energy technologies. These programs give U.S. firms an opportunity to introduce their technologies to a large audience of users and to focus on situations in which governmental support of the U.S. firms will provide a significant advantage in international markets.

Activities

Former Soviet Union and Eastern European Programs

In 1992, two major oil conferences took place to support U.S. energy industries in the former Soviet Union. The first conference, in January 1992, was in Tyumen, Russia. More than 60 American oil industry executives went to Tyumen seeking ways to invest in Russia's oil industry. The second conference, in November 1992, was in Alma Ata, Kazakhstan. The major objectives of this conference were to exchange information and establish contacts between senior private- and public-sector decision-makers. U.S. participants learned about the structure of the Kazakh oil and gas industry. The Government

of Kazakhstan outlined their priority investment opportunities in all sectors of the oil and gas industry.

In October 1992, OEA held a workshop at the Oak Ridge National Laboratory to inform high-level officials from the Russian Ministry of Fuel and Energy about the organization and regulation of the U.S. electric power industry and on electric power technologies.

In cooperation with the Trade and Development Agency and the Department of Commerce, OEA hosted a conference in July 1992 in Prague, Czechoslovakia, on U.S. electric power technologies. The objective of the conference was to bring together key decision-makers from central and Eastern Europe and the former Soviet Union and technical experts from the private sector in the United States to share information.

Because of overwhelming requests from U.S. industry, OEA, in cooperation with the Trade and Development Agency and the Department of Commerce, sponsored a second conference on U.S. electric power technologies in September 1993 in Budapest, Hungary. At this conference, Eastern European and former Soviet Union participants discussed the status of the electric power industry in their countries one year after the previous conference. Participating U.S. firms conducted workshops for the Eastern European and former Soviet Union participants on issues that are key to expanded cooperation.

In December 1992, a major conference on electrical power technologies took place in Moscow. The U.S. Agency for International Development cosponsored and cofunded this conference. The 65 U.S. private sector and government participants and over 100 Russian participants from state ministries, regional utilities, and key powerplants reported that the formal and informal interactions and presentation have created a strong foundation for future business ventures.

A small delegation of U.S. electric power companies visited Vladivostok, Russia, to study future electric power development plans of the region and to introduce U.S. energy technologies. A followup program is being discussed with industry.

In cooperation with the U.S. Agency for International Development, the Edison Electric Institute, and the U.S. Energy Association, OEA sponsored the United States/Russia Utility Management Seminar for 70 heads of Russia's joint stock utilities in August 1993 in Tucson, Arizona. That seminar continued the process of collaboration to provide an increasing supply of electric power to fuel economic growth and raise the standard of living in Russia, while reversing the environmental problems of the past.

Asia Program

To encourage increased participation of U.S. industry in the Thai electric power expansion programs, OEA sponsored a mission to the United States in November 1992 led by the Governor of Thailand's two transmission and distribution utilities. This delegation met with representatives of U.S. transmission and distribution equipment and service suppliers. Followup activities have resulted in two sister utility agreements with a U.S. electric power utility.

In November 1992, OEA organized a conference in Bangkok, Thailand, that focused on Asia as a major market for U.S. energy exports. This meeting brought together key officials from the oil industries in 12 Asian countries to discuss environmentally sound technologies for finding and producing oil and gas. The Trade and Development Agency, the Department of Commerce, and the Department of the Interior supported the effort. This conference initiated a DOE-maintained Asian-American dialog on environmental issues associated with exploration.

In cooperation with the Department of Commerce and Exim Bank, OEA sponsored a successful electric power mission to China in June 1993. Three day-long conferences took place in Beijing, Shanghai, and Guangzhou that included 24 U.S. energy companies. Following the mission to China, Department of Energy Secretary Hazel O'Leary initiated a "U.S. Government and Industry Partnership to Promote Electric Power Industry Trade with China" to build on relationships established during the June mission and to reduce trade barriers between the United States and China in the electric power equipment and services market. Secretary of Commerce Ronald Brown is cosponsoring the Secretary's initiative, which includes nine other U.S. Government agencies as well as industry participation. The program will include an exchange of information on electric power issues and technologies, greatly increase contact with China and include an ambitious program of missions and seminars. In 1994, Southern China alone is predicted to purchase over \$6 billion of foreign equipment for electric power projects.

In July 1993, the Departments of Energy and of Commerce led a delegation of industry energy experts to Indonesia to study the Indonesia electric power market, identify key factors affecting competitiveness in the market, and develop recommendations for a Government-industry partnership to increase U.S. commercial success. DOE has released a report on the information developed by the mission, and OEA is in the process of developing a strong program of followup activities.

ENERGY SUPPLY AND INTERNATIONAL ENERGY POLICY

Electricity Policy

The Department's electricity policies emphasize the development of reliable, environmentally clean, and economical electric power. To achieve this objective, the Department has undertaken a broad spectrum of initiatives that promote the increased use of renewable resources and natural gas for electricity generation, support state and utility integrated resource plans, and remove barriers to the efficient generation and transmission of electricity. Many of these initiatives also support implementation of EPACT.

The Office of Electricity Policy has undertaken an analysis of the total fuel-cycle costs of electricity generation and energy efficiency technologies to help Federal and state policy-makers and other stakeholders determine the environmental impacts associated with electricity production, transmission, and use. The Office of Electricity Policy also is evaluating the impacts of ratemaking and tax policies on the cost of renewable and conventional generation technologies. This analysis will investigate the impact of governmental policies on electricity resource development.

The Department sponsored several workshops and technical conferences with Federal and state regulators and other stakeholders to develop methods to resolve energy issues. These workshops and conferences have evaluated the impact of Federal and state regulatory procedures on the development of an allowance trading market, explored options for electricity transmission access and pricing policies, analyzed integrated resource planning programs, and reviewed approaches for the development of regional transmission groups.

At the direction of the President, the Department is participating in an interagency task force to develop a plan to reduce the Nation's greenhouse gas emissions to 1990 levels by the year 2000 in a flexible, nondisruptive, and cost-effective manner. For electricity, the Department is considering options that will expand the use of renewable energy for electricity generation; develop and promote energy efficiency and conservation technologies; increase the use of natural gas, where cost-effective; increase the use of clean coal and nuclear generation technologies; support the export of U.S. energy and efficiency technolo-

gies; and expand the Department's Integrated Resource Planning Program to assist states and utilities in considering actions that will help reduce emissions of greenhouse gases.

Future activities of the Department will facilitate the use of clean domestic fuels and technologies, support environmental improvements, promote the export of U.S. environmental and energy efficiency technologies, and promote economic growth and employment. These activities will include fostering a more favorable regulatory climate; encouraging the use of efficient, low-emitting technologies; and replacing older, less efficient, and often dirtier generating plants. The Department also will develop methods to make the regulatory process work more efficiently and to reduce the cost of Federal regulation.

The Department will continue its support for a constructive dialogue between Federal and state agencies. State regulatory practices have a major impact on the development of competitive wholesale electricity markets, and many states are implementing integrated resource planning programs that include a consideration of environmental externalities. The Department will provide assistance to states in addressing these and other issues and monitor the states' activities.

International electricity trade in North America provides significant benefits in terms of reduced rates and lower environmental impacts for consumers in the United States, Canada, and Mexico. The North American Free Trade Agreement contains provisions that will increase the opportunity for U.S. companies to build, own, and operate electricity-generating facilities in Mexico. The Department will support actions to reduce barriers to international trade and promote the export of U.S. energy and conservation technologies.

The Department will explore opportunities to improve energy efficiency and cost-effectiveness of pollution prevention technologies and processes via source reduction and waste minimization. The Department will also promote export of U.S. technologies to reduce greenhouse gases and other emissions in developing nations.

Oil and Natural Gas Policy

The Office of Policy, Planning, and Program Evaluation led efforts to develop initiatives that would increase the utilization of natural gas. Based on recommendations

of the office, the Federal Energy Regulatory Commission promulgated a rulemaking to require that natural gas pipelines provide transportation services to third parties that were comparable to the services that a pipeline provided to itself. This rule also adopted reforms in the pricing of natural gas pipeline services that will result in increased utilization of natural gas. As a result of this rule, significant new responsibilities will shift from the federally regulated pipeline companies to local distribution companies and state public utility commissions. In recognition of that trend, the Office of Policy, Planning, and Program Evaluation organized a conference with the National Association of Regulatory Utility Commissioners to examine the implications of this shift in responsibility. The conference took place in New Orleans in April 1993 with more than 700 state and industry officials in attendance. The Office of Policy, Planning, and Program Evaluation was also active in providing analysis to the Administration and Congress in the passage of EPACT. An initiative sponsored by the office to remove impediments to imports and exports of natural gas was in the final legislation. The office also supported the Administration's efforts to develop initiatives that would permit natural gas to be substituted for fuels that have greater greenhouse gas emissions to achieve the President's commitment to stabilize greenhouse gas emissions at 1990 levels. Similarly, the Office of Policy, Planning, and Program Evaluation developed initiatives for the Secretary's Domestic Energy Initiative to permit greater utilization of natural gas where it would displace oil imports.

For the oil sector, the office focused on activities to expand U.S. oil and gas supplies; reduce vulnerability during supply disruptions; and provide for the clean, efficient use of oil resources. To support debate on EPACT, analyses were conducted on tax laws relating to petroleum production, objectives for strategic petroleum stocks, oil pipeline regulatory reform, and oil and gas supply enhancement through use of advanced technologies. The Office of Policy, Planning, and Program Evaluation also participated in the National Petroleum Council's study of the effect of environmental requirements on the U.S. refining industry. In addition, under the title of the Domestic Natural Gas and Oil Initiative, the office conducted a series of meetings with individuals, interest groups, and businesses holding a stake in the future of the domestic oil and gas industries. The suggestions presented in the meetings became the basis for policy options, which the office developed and analyzed.

International Energy Activities and Trade Policy

Introduction

Recognizing the worldwide nature of energy markets, and particularly the oil market, the United States pursued energy policies that promoted a diverse and flexible international energy supply system, removed barriers to the development of economic energy resources, improved the international capability to respond to energy emergencies, and addressed international environmental concerns and commitments. These goals called for increased emphasis on international collaboration in basic research, global environmental problems, and assistance in helping other countries plan for energy use, as well as other complementary goals. U.S. national interests are served when all nations allow markets to work, diversify their sources of supply, invest in energy conservation, build strategic stocks to be used in times of market disruption, remove energy trade barriers, and cooperate in the development of new energy technologies. Pursuing these critical energy interests is the role of the Department's Office of Policy, Planning, and Program Evaluation. In addition, the office was responsible for and directly involved in an active program of promoting mutually beneficial international collaboration in energy-related research and development. This activity has grown in importance as the Department has become increasingly involved in enormously complex and expensive research and development projects, such as the International Thermonuclear Experimental Reactor (ITER), the Human Genome Program, advanced facilities for basic physical science, and the extensive range of research related to global climate change.

Since the 1973–1974 Arab oil embargo, there has been a fundamental restructuring of energy supply and demand systems in the world economy. The sharp price hikes of the 1970s, coupled with increased reliance on market forces and reduced reliance on Government regulation and other intervention, have resulted in lower world oil consumption, increased use of nonoil energy sources, and increased oil production in countries other than members of the Organization of Petroleum Exporting Countries.

In 1990, average world oil demand, excluding former or current centrally planned economies, was higher by 1,050,000 barrels per day (144,000 metric tons per day) than the previous peak demand year, 1979, when total demand for the market economies averaged 52,064 million barrels per day (MMBD) (7.13 million metric tons

per day). Supply from nations that are not members of the Organization of Petroleum Exporting Countries has increased by about 6.0 MMBD (800,000 metric tons per day) since 1979. Market economy oil demand increased by 730,000 barrels per day (100,000 metric tons per day), or 1.3 percent, during 1991, to average 54.8 MMBD (7.5 million metric tons per day), and latest estimates for 1992 show demand growing another 500,000 barrels per day (69,000 metric tons per day), compared with the previous year.

U.S. oil demand increased slightly during 1987 and slightly more in 1988 and 1989, remaining well below prior peak levels. During 1990 and 1991, oil demand declined slightly. In 1992, U.S. demand increased 320,000 barrels per day (44,000 metric tons per day) over the previous year to average 17.0 MMBD (2.33 million metric tons per day). In 1993, U.S. demand averaged 17.2 MMBD (2.36 million metric tons per day), a smaller increase of 160,000 barrels per day (22,000 metric tons per day). Table 20–1 provides some comparative figures.

Table 20–2 shows the leading oil exporters to the United States ranked by their position in 1987. Saudi Arabia, which ranked ninth in 1985, rose to third in 1987 and first from 1988 through 1993. Saudi petroleum exports to the United States in 1992 averaged 1.720 MMBD (236,000 metric tons per day), down 4 percent, and 1.408 (193,000 metric tons per day) in 1993, down 21 percent from 1992.

Multilateral Initiative in the Asia-Pacific Region

In 1992 and 1993, the U.S. continued its active participation in the Asia-Pacific Economic Cooperation (APEC) forum and played a leading role in the development of meaningful energy-related policies for APEC, whose membership has grown from 12 member economies when it was first established in 1989 to 15 members in 1993 from throughout the Asia-Pacific region. DOE's involvement in APEC's program on regional energy cooperation included holding the chairmanship of expert groups on both the energy and environment, and energy efficiency and conservation themes. During 1993, DOE worked with its fellow members in planning APEC workshops on electric power demand-side management (held during May 1993 in Korea) and clean coal technology (held during September 1993 in Thailand). Executives from the private sector participated in both of these events, and it is envisioned that future APEC activities, including workshops on alternative fuels and programs for renewable energy will also include representatives from the private sector.

Table 20-1—Comparative statistics on domestic oil demand and imports

Year	Domestic oil demand		Net oil imports		Net imports of crude oil		Net imports of petroleum products		Net oil imports as percentage of domestic product demand	Gross imports of petroleum products as percentage of domestic product demand
	millions of barrels per day		(million of metric tons per day)		(million of metric tons per day)		(million of metric tons per day)			
Year of Arab oil embargo (1973)	17.31	(2.37)	6.0	(0.8)	3.2	(0.4)	2.8	(0.4)	35%	17%.
Year of all-time high (1977)	18.43	(2.52)	8.6	(1.2)	6.6	(0.9)	2.0	(0.3)	47%	12%
Recent years										
1989	17.33	(2.37)	7.2	(1.0)	5.7	(0.8)	1.5	(0.2)	42%	13%
1990	16.99	(2.33)	7.2	(1.0)	5.8	(0.8)	1.4	(0.2)	42%	12%
1991	16.71	(2.28)	6.6	(0.9)	5.7	(0.8)	0.9	(0.1)	39%	11%
1992	17.00	(2.33)	6.9	(0.9)	6.0	(0.8)	0.9	(0.1)	41%	11%
1993 ^a	17.19	(2.36)	8.5	(1.2)	6.7	(0.9)	1.8	(0.2)	50%	10%

^aEstimated.**Table 20-2—Leading petroleum exporters to the United States, in average barrels (metric tons) per day**

Country	1991		1992		1993 ^a	
Canada	1,031,000	(141,000)	1,005,000	(138,000)	1,175,000	(161,000)
Venezuela	1,014,000	(139,000)	1,161,000	(159,000)	1,285,000	(176,000)
Saudi Arabia	1,795,000	(246,000)	1,720,000	(236,000)	1,408,000	(193,000)
Mexico	801,000	(110,000)	706,000	(97,000)	919,000	(126,000)
Nigeria	702,000	(96,000)	680,000	(93,000)	738,000	(101,000)
United Kingdom	136,000	(19,000)	219,000	(30,000)	340,000	(47,000)
Algeria	252,000	(35,000)	196,000	(27,000)	220,000	(30,000)
Indonesia	111,000	(15,000)	75,000	(10,000)	81,000	(11,000)
Virgin Islands	243,000	(33,000)	161,000	(22,000)	254,000	(35,000)
Angola	254,000	(35,000)	336,000	(46,000)	330,000	(45,000)
Colombia	162,000	(22,000)	123,000	(17,000)	166,000	(23,000)
Norway	81,000	(11,000)	125,000	(17,000)	124,000	(17,000)
Trinidad and Tobago	87,000	(12,000)	95,000	(13,000)	73,000	(10,000)

^aEstimated.

In addition, DOE hosted the October 1993 APEC Ministerial Meeting in Seattle, which was followed by an informal meeting of APEC member economy leaders hosted by the President on November 20, 1993.

Bilateral Consultations

In addition to leading the U.S. delegation to the biennial International Energy Agency (IEA) ministerial meetings, the Department participated in a number of formalized bilateral energy working groups with both producer and consumer countries. Through such arrangements, the Department seeks to coordinate energy policies, develop markets for U.S. energy exports and technology, and expand areas of cooperation in energy. The technical level of these bilaterals has made them an effective means of building close and cordial working relationships with our stakeholders and counterparts in other energy ministries. They also help us to better understand their perspectives on our energy policy.

The annual bilateral energy consultations, held alternately in Brussels, Belgium, and Washington, D.C., were established by DOE and the Department of State with the Commission of the European Communities in May 1990. The talks provided an opportunity to exchange views on current energy policy developments, with particular reference to international issues. The 1992 talks focused on the aftermath of the Persian Gulf War on international energy markets, the proposed European Energy Charter, and developments in Eastern Europe. These groups generally meet twice a year and followup is achieved through our embassies and through meetings of experts on a variety of energy issues. We have similar bilaterals with Australia, Canada, Indonesia, Japan, Korea, Kuwait, Mexico, Saudi Arabia, the United Arab Emirates, Venezuela, and a number of other countries in Europe and Latin America.

North America Free Trade Agreement

In line with NAFTA, DOE is coordinating initiatives between the governments of Canada, Mexico, and the United States to further mutually beneficial gas developments. The three governments plan to undertake a joint study evaluating new markets, trade barriers, and environment considerations affecting gas demand growth.

Natural Gas

Pursuing Administration initiatives to develop and utilize public-private sector partnerships has led DOE to enlist the support of the U.S. gas industry to further interna-

tional natural gas programs. DOE believes there exists considerable commonality between government policy efforts in natural gas consumption and trade and private sector interest in overseas opportunities and investment. An example of this mutually beneficial activity is the United States/Gazprom Working Group. DOE, along with EPA, has formed a unique coalition of U.S. Government, U.S. private sector and ROA Gazprom, the Russian natural gas concern. Known as the U.S./Gazprom Working Group, its objectives are to develop tangible projects in Russia that will: (1) increase the efficiency of natural gas production and delivery in the Russian Federation to free additional gas supplies for domestic use and export; and, (2) reduce emissions of global and local pollutants such as the greenhouse gases methane, carbon dioxide, nitrogen oxide, and carbon monoxide. These projects help fulfill President Clinton's initiatives to help Russia transform its energy economy into a market-oriented, efficient, and environmentally protected system. At the same time, the public-private sector partnership worked to establish commercial projects between American and Russian energy companies. Additionally, DOE continued to sponsor conferences in Russia and various republics of the former Soviet Union to help U.S. firms enter the earliest stages of project development.

DOE continued to rely on its traditional government-to-government approach to international natural gas policy through regular, bilateral consultations with foreign governments concerning the supply, security, and pricing of natural gas. As an outgrowth of the North American Free Trade Agreement, Energy Secretary O'Leary and Mexican Energy Minister Lozoya agreed in 1993 that it would be useful to undertake a joint gas study to ensure that issues relating to the most efficient use of that resource are identified and resolved. The Canadian government will also participate. It is expected that the study will be directed by a high-level policy steering group, with input from industry. The estimated timeframe for completion is about a year. Areas to be addressed include laws and regulations, a timetable for demand growth, the effect of changing environmental regulations, the ability to get long-term contracts, and financing for necessary pipeline interconnections. DOE also promotes an active natural gas agenda in international energy organizations, such as IEA and the Committee on Gas of the United Nations Economic Commission for Europe. Through these organizations, the Department has pursued programs that stress the security and environmental benefits of expanded natural gas use. During 1992, DOE initiatives at IEA promoted the development and application of natural gas technology and to increase the international cooperation between industry

and government in finding new and diverse applications for U.S. gas supplies.

Under the Committee on Gas of the United Nations Economic Commission for Europe, the Department continued its active role in exploring the potential of natural gas as an alternative motor vehicle fuel and in examining new developments in the integration of gas pipeline systems between the countries of Eastern and Western Europe and the Commonwealth of Independent States. Additionally, through the Committee on Gas, DOE is supporting research and cooperative efforts to protect the environment through increasing gas pipeline safety and reducing methane emissions.

DOE helped to develop and share new gas technologies through the Energy Project of the Asia-Pacific Economic Cooperation effort to increase energy efficiency, conserve limited gas supplies, and mitigate the environmental problems associated with energy use. The development of compressed natural gas for motor vehicle use is also a focus of this project.

Eastern European Energy Strategy and Activities

The Department's Eastern European Energy Strategy, first developed in 1989, is designed to help the countries in the region restructure their energy systems in ways that promote economic and political reform. The key elements of the strategy are to encourage the following:

1. Market-based energy pricing and removal of barriers to trade and investment in energy
2. Improved efficiency in the production, transportation, and use of energy
3. The use of environmentally sound technologies and practices
4. Diversity of supply through sound development of indigenous resources, enhanced safety in nuclear power, and greater integration of East-West energy markets

This strategy is designed to address a host of energy problems facing countries in the region. While the energy mix, resource base, and energy infrastructure of Eastern European countries vary, the countries face a number of common energy challenges.

Energy production, transmission, and consumption are highly inefficient; the region consumed 50 percent more energy per unit of national income than the industrialized countries, and reliance on energy-intensive heavy industries has hampered energy efficiency improve-

ments. Deteriorating and obsolete energy production and transportation systems are pervasive and result in localized energy shortages and substantial energy losses; for instance, electricity transmission losses are, in many cases, two to three times their level in Western economies.

Coal, a substantial portion of which is of the highly polluting brown coal variety, provided more than 50 percent of the region's energy requirements and contributed to severe environmental problems. Other indigenous energy resources are modest, leading to a very high level of dependence on imported oil and gas, the bulk of it still from the former Soviet Union. New pipelines and enhanced electricity systems needed to improve the linkages between Eastern Europe and other European trading partners were, in most cases, still in the planning stages.

Nuclear safety in Eastern Europe has been a particular area of concern to the United States and other industrialized countries, because several of the region's reactors are of the old Soviet-designed 440/model 230 variety, which lacks safety features considered mandatory in the West. The United States is participating in an intensive international effort to improve the safety of these reactors until safer alternatives can be put in place.

The Department's activities in Eastern Europe are designed to address these and other issues. The DOE program was implemented in close cooperation with the U.S. technical assistance program for Eastern Europe and coordinated by the Department of State and the U.S. Agency for International Development. The DOE program includes energy infrastructure projects, feasibility studies, demonstration projects, training programs, country and regional assessments of energy policies, science and technology cooperation programs, and export promotion activities.

The following projects highlight the Department's role in the region.

European Energy Charter

Since July 1991, the Department has been participating in U.S. delegations, led by the Department of State, to develop a framework for integrating the countries of Eastern Europe and the Commonwealth of Independent States into the global energy market, by encouraging market-based energy systems and improved energy trade and investment regimes. This effort has led to the European Energy Charter, signed in December 1991, and an ongoing effort to supplement the charter with an implementing agreement and supporting protocols in the areas of energy efficiency and nuclear safety. Negotiations are expected to continue into 1994.

Retrofit of Polish Coal-Fired Powerplants

DOE implemented the retrofit of a coal-fired powerplant in Poland to help fight air pollution in that country. This \$10 million program funded the design and installation of a U.S. state-of-the-art scrubbing system that was largely fabricated in the United States. The plant was dedicated in November 1993 and is expected to be operational in the spring of 1994. Once operational, the project will allow the Skawina powerplant in Poland to be the first to come into compliance with Poland's new sulfur dioxide control requirements.

Air Pollution Reduction in Krakow

DOE managed a \$20 million, multiyear program, begun in 1991, to identify ways to reduce air pollution from "low emissions" sources in Krakow, Poland. These sources are made up of the nearly 3,000 small coal-burning boilers and 125,000 individual home coal stoves. Following a major project solicitation, DOE selected nine projects in September 1993 to carry out the commercial phase of the program. The projects have a total cost of \$31 million, with DOE providing approximately \$14.5 million. Final agreement with all parties was expected to be reached in the first quarter of 1994.

Regional Energy Efficiency Project

DOE continued to participate in the Regional Energy Efficiency Project of the U.S. Agency for International Development. Launched in 1991, the project is a 4-year, \$34 million effort to assist in the region's energy reform and restructuring programs. DOE received \$3.9 million in 1991 and more than \$5 million in 1992 under this project to provide technical assistance in energy efficiency, nuclear safety, and renewable energy systems.

Nuclear Safety

As part of the Regional Energy Efficiency Project, DOE received \$2.4 million in 1991 and \$2.9 million in 1992 for activities in the area of nuclear safety. Under this program, DOE, in coordination with the U.S. Agency for International Development and the International Atomic Energy Agency, initiated a number of nuclear safety projects in Eastern Europe. These included training workshops, expert missions, fellowship programs, assistance in planning and analysis, and the provision of safety equipment, such as a plant transient analyzer for Bulgaria. U.S.

Agency for International Development funding to DOE for nuclear safety reached nearly \$3 million in 1993.

Energy Assessments

DOE has provided experts on international teams assessing the energy situations and policies of the Czech and Slovak Federal Republics, Hungary, Poland, and Romania. In addition, the Department in 1992 published a review of the energy situation of the Baltics (Estonia, Latvia, and Lithuania). In 1993, a comprehensive summary of the energy and electricity situations of each of the Eastern European countries was prepared for dissemination to U.S. industry seeking new markets in the region. This survey will be the basis for a comprehensive review of electricity in Eastern Europe planned for 1994.

During 1993, DOE received funding from the Department of State for three U.S./Baltic collaborative projects: wind energy assessments in Estonia, Latvia, and Lithuania; oil shale utilization in Estonia; and photosynthesis studies in Estonia and Lithuania.

Bilateral Science and Technology Agreements

DOE is participating in the bilateral science and technology agreements managed by the Department of State with the Czech and the Slovak Republics, Hungary, Poland, and the Republic of Slovenia. The Department of State contributes \$5 million to the program, divided and matched by these countries. Joint energy research and development projects of mutual interest are funded under this in fields such as energy efficiency, fossil energy, renewable energy, nuclear safety, and basic energy sciences. Department of Energy projects receive 10 to 15 percent of the total budget.

Promotion of United States' Capabilities and Technologies in Eastern Europe

The Department's programs in Eastern Europe were designed to be responsive to the energy security and trade interests of the United States while responding to the urgent needs of the Eastern European countries for technical expertise and modern energy systems and technologies.

An important focus of DOE's activities in Eastern Europe was to promote the capabilities and technologies of American companies wishing to enter this potentially vast market for energy and environmental technologies and services. DOE has sponsored two conferences in the region, in cooperation with the Department of Commerce and the U.S.

Trade and Development Agency, to showcase U.S. electric power technologies. The first conference was held in Prague in July 1992, and the second in Budapest in September 1993. Romania has offered to host the next electric power conference in 1994.

Western Hemisphere Energy Strategy and Activities

Since its 1990 Report to Congress on Western Hemisphere Energy Cooperation, in which the Department explored areas for possible cooperation with its neighbors in the Caribbean and Latin America, DOE has been extremely active in the area. The dramatic changes in the world since the fall of the Berlin wall—events in the Persian Gulf, the decline of the former Soviet Union, work toward the development of a European common market, continued instability in the Middle East—highlight the relative stability that we possess in the Western Hemisphere. The energy security of the United States is directly related to the overall stability and energy policies of Latin America and the Caribbean. As the Department expands its interaction and cooperation with Western Hemisphere countries, it also curtails this country's dependence on unstable oil supplies and strengthens the U.S. economy, as well as those of its neighbors.

Venezuela and Mexico accounted for 91 percent of 120 billion barrels of proven conventional crude oil reserves in the region, a level over 4 times the current U.S. oil reserves. Nine other countries in the Caribbean and Latin America (Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Guatemala, Peru, and Trinidad and Tobago) also have oil reserves. These reserves enhanced supply security, provided an important source of energy to their domestic economies, and, in some cases, foreign exchange income. Development in this area also decreases regional demand for crude oil from sources outside the hemisphere.

Privatization of the region's energy sectors has gone beyond being a phenomenon in a few countries to a trend that is sweeping the region. Throughout the hemisphere, countries are turning away from statist economic and political policies that stifle growth and are looking instead to the power of the free market. In South America, Argentina, Chile, and Colombia set standards for future efforts in privatization for their neighbors to follow. Several Central American countries, including El Salvador, Guatemala, and Honduras, were also considering privatizing several of their state-run companies. Our neighbors are seeing that foreign investment, global competition, and

increased trade do not mean that they have to relinquish their national pride.

DOE explored additional avenues for cooperation between the Caribbean, Latin America, and the United States in the following areas:

1. Forums to advance greater foreign and private-sector investment in the region's energy sector
2. Interamerican conventions for drilling practices, particularly offshore practices, as they relate to environmental concerns
3. Exchanges of information between our counterparts in the region and other nonprofit entities, and promotion of exchanges of personnel between various energy-related public and private entities
4. Cooperation between gas producers, the gas transportation industry, and environmental groups
5. Support for energy service-related businesses for promoting energy efficiency and energy savings
6. Hemispheric incentives for independent electric power generation fueled by natural gas
7. Regional demonstration programs promoting the use of alternative-fuel vehicles
8. The use of renewable energy technology in meeting the demand for electric power generation in rural areas

In 1992 and 1993, the Department continued to work with its neighbors on a number of cooperative efforts. Argentina, Brazil, Chile, Colombia, Mexico, and Venezuela are some of the countries with which cooperative efforts were undertaken during this period. Examples of hemispheric cooperation include negotiations on the energy portion of the North American Free Trade Agreement; regular energy bilaterals with Mexico and Venezuela; consultation on renewable rural electrification projects in Brazil; regional conferences on the oil and gas industry, including participation in multilateral meetings with organizations such as the Association for Latin American Oil Companies and the Latin American Energy Organization; and discussion with Colombia on entering into a cooperative arrangement on data base development, renewables, regulatory framework development, and energy efficiency.

The United States recognizes that each nation in the region must make its own choices. There is no blueprint for achieving economic growth and energy security. The primary responsibility for this lies with each individual country. Our challenge in the United States and the Department is to respond in ways that support the positive changes now taking place in our hemisphere.

DOE was extremely active in the Inter-Agency Working Group preparing for the Summit of the Americas in December 1993. We have participated in the Economic Sub-Working Groups of Trade and Investment, Infrastructure, Private Sector, and Sustainable Development. DOE has promoted an Initiative on the Sustainable Use of Energy, which will likely be a main focus for the summit and a follow-up conference of all energy and environment ministers. The sustainable use of energy includes programs of energy efficiency and renewable energy, as well as the promulgation of stronger regulatory frameworks, all of which allow countries of this hemisphere to have greater energy security and larger economies.

International Affairs

International Energy Agency

Energy has always significantly influenced economic development. The availability of all forms of energy, especially oil, has affected the global economy and led to profound changes. The members of the International Energy Agency (IEA) joined together in 1974 to safeguard their collective energy security and associated economic security through international cooperation. At that time, IEA governments committed themselves to take effective measures to meet any oil supply emergency and to reduce dependence on oil through measures such as increased energy efficiency, conservation, the diversification of energy supplies, and the development of new technologies.

IEA is undergoing a new orientation, beginning with the expansion of the definition of energy security to include broad energy and environmental problems and relations with nonmember countries, in addition to oil emergency preparedness. At the June 1993 IEA Ministerial, the Secretary helped steer IEA's mission in this new direction by stating that U.S. energy policy both domestically and internationally will focus on increased energy efficiency and conservation, environmental improvement, and stronger relations with developing and transition economies. Also at the Ministerial, the Secretary joined others in calling for a "brainstorming" session on environmental policies, particularly global climate change, to occur in spring 1994.

During the 1990s, the world is expected to face a fundamental change in the global energy balance. Energy demand, which was approximately equal in OECD and non-OECD countries in 1990, will be substantially higher

in non-OECD countries by the end of this decade. Markedly higher growth rates in the non-OECD region ensure that these countries will account for more than half of world energy demand by the late 1990s. Therefore, IEA is strengthening its relations with economies in transition and developing countries by analyzing energy-related developments in energy-producing and -consuming countries worldwide and by examining energy policy decisions of IEA in a global context. For example, IEA is making a serious commitment to analyzing the energy situation in Central and Eastern Europe and the Newly Independent States.

IEA has expanded its country energy sector review process to include nonmembers and has published energy surveys of the Baltics, the Czech and Slovak Republics, Hungary, Poland, and Romania. Many of these countries have requested followup reviews by IEA to help them monitor their progress in energy reform.

In addition, IEA was actively involved in multilateral activities such as the negotiations on the European Energy Charter and the Conference on Coordination of Assistance to the Newly Independent States. Moreover, IEA and OECD are jointly developing a register of energy assistance offered to and requested by the Newly Independent States to provide useful information both to aid donors and recipients and to avoid duplication of effort.

Finally, in the Asia-Pacific region and Latin America, where energy demand has experienced particularly rapid growth, IEA began working to develop closer relations with countries like Mexico and the Republic of Korea, which seek IEA membership.

IEA has increased its emphasis on the protection of the environment from energy-related degradation. Environmental policies are now major factors affecting world energy production, transportation, processing, and consumption. IEA helped member and nonmember countries in the analysis of energy security and economic impacts of the various options to reduce energy-related environmental impacts. A new division in charge of carrying out a specific program of analysis of energy and environmental issues was created in 1992. This division was preparing a series of studies on greenhouse gases, energy efficiency, and climate change policy initiatives, including an examination of the effects on energy markets of government policies aimed at limiting climate change.

In 1993, IEA conducted studies to compare national policies on the reduction of greenhouse gas emissions, on electricity and the environment, and on transport and the environment. IEA is an active contributor to the Interna-

tional Panel on Climate Change and is involved in the followup to the United Nations Conference on Environment and Development. Further studies are anticipated in 1994.

Looking beyond the 1990s, IEA continues to stress the importance of maintaining momentum in energy research and development programs through international collaboration. Collaboration in energy technology and research and development has been a fundamental element of IEA work for over 15 years. Through the initiative of member countries, IEA has set up more than 60 implementing agreements linking member countries in R&D and technology demonstration and information initiatives. More than half of these agreements are in progress, and new agreements and projects are regularly being added. Some agreements focus on more efficient energy use, such as district heating and demand-side management, while others are of direct benefit to the environment as well as to saving energy, such as fluidized-bed combustion for clean burning of coal, and techniques for controlling atmospheric emissions in electricity generation and industrial use. For instance, DOE has led the initiative to establish the IEA International Center for Gas Technology Information, which is structured to provide technology information exchange, and technology analysis and transfer. Several projects examined the possibilities of unconventional renewable energy sources, such as wind and solar power generators. Others dealt with future technologies, such as nuclear fusion power, whose commercial application may be decades away. Nonmember countries may also participate and contribute to the agreements under special conditions.

Nuclear Energy Agency

The Nuclear Energy Agency (NEA), a companion organization to IEA and headquartered in Paris, also is an element of OECD. NEA seeks to promote the safe and effective use of nuclear energy through the exchange of information among technical experts, through analytical studies, and through research and development projects among member countries.

NEA operates through a series of committees composed of NEA experts in the fields of nuclear safety, radioactive waste management, radiation protection and public health, the nuclear fuel cycle, and nuclear science. DOE serves as the lead U.S. agency in NEA's projects and activities, with support from the Department of State, the Nuclear Regulatory Commission, and the Environmental Protection Agency.

International Energy Research and Development Cooperation

DOE engaged in a number of bilateral and multilateral R&D arrangements involving a wide range of science and technology issues, and the expertise of national laboratories and other research institutions. These international energy R&D arrangements generally contemplate one or more of the following forms of cooperation: exchange of information; exchange of samples, materials, instruments, and components for testing; exchange of scientists, engineers, and other specialists; visits by individual specialists or teams of specialists; seminars and other meetings; and joint projects in which each party shares the work and costs. The joint cooperation may be conducted under broad umbrella agreements, implementing arrangements, or an exchange of letters. The benefits of international cooperation include the following:

1. DOE and its partners efficiently combine their efforts to economize resources, including money, personnel, and facilities. Each party may then accomplish its objectives at less cost, or achieve more results for the same total expenditure.
2. Foreign parties gain information on DOE research and technology. Foreign parties may advance their knowledge in areas critical to U.S. interests, such as nuclear safety, nonproliferation, and global climate change. This also promotes the marketing of U.S. innovations in energy-related technology and introduces the U.S. private sector to interested foreign parties.
3. The U.S. and DOE gain a better understanding of and access to foreign technology. This allows DOE to avoid unnecessary research duplication, to validate the results of domestic experiments, and to benefit from advances in foreign research.
4. The global scientific community benefits from the long-term synergistic effects of cooperation.

Multilateral Cooperation

In addition to R&D conducted under IEA and NEA, DOE also participated in a number of other multilateral research projects. The International Thermonuclear Experimental Reactor, or ITER, project is a prime example.

International Thermonuclear Experimental Reactor

In mid-1992, the United States and the European Community, Japan, and the Russian Federation signed a four-

party agreement to conduct engineering design activities for the ITER Program. The major objective of such a future facility would be to demonstrate the scientific and technological feasibility of fusion power. The tasks to be performed during the engineering design phase of the ITER activity include detailed design of the device and the necessary supporting R&D. Following the completion of this phase in July 1998, the four ITER parties will make their decisions on whether or not to construct ITER, and whether or not to construct ITER alone or to collaborate with other parties in the construction.

During 1992, researchers continued work in their home laboratories in support of ITER. With the start of the engineering design activities, three multinational teams are located at three cocenters: Garching, Germany; Naka, Japan; and San Diego, California.

Bilateral Research and Development Cooperation

Russia

The dissolution of the Union of Soviet Socialist Republics in January 1992 brought major changes in U.S. cooperative and assistance efforts with the newly formed political structure in Russia and other republics of the former Soviet Union. As a first step, the Agreement on the Peaceful Uses of Atomic Energy was modified to allow government-to-government cooperation in established fields with each of the countries of the former Soviet Union as conditions warrant. In Russia, DOE's primary cooperating partner is the Ministry of Atomic Energy and its various R&D institutes. In mid-1992, funds were provided under Nunn-Lugar legislation to support nuclear safety assistance to Russia and Ukraine. This was supplemented with funding under the Freedom Support Act. Support was provided for the construction of two reactor simulators, detailed systems analysis, development of extensive emergency operating procedures, and a number of significant risk reduction efforts primarily related to fire safety. DOE and the Nuclear Regulatory Commission will consider assisting the proper operations of Russian and Ukraine nuclear facility regulatory bodies.

DOE also expanded cooperation in the radiological health effects area to work directly with the Ukraine and Belarus Governments. DOE signed an agreement with the Russian Mayak Research Institute for the purchase of 5 kilograms of plutonium-238 as part of the U.S. research and development efforts on space nuclear power. Factfinding visits and technical meetings were also held on space power technology and safety. DOE and Kazakhstan Government representatives discussed envi-

ronmental restoration and waste management, and radiological health effects as specific concerns resulting from nuclear weapons testing at Semipalatinsk.

In January 1992, a U.S.-Russia Gas Conference took place in Tyumen, Western Siberia. The workshop benefited from U.S. private-sector participation in exploring cooperation and in making technology presentations. Since mid-1992, U.S.-Russian cooperation in nonnuclear fuels and energy received major attention. Discussions with Russian Government representatives resulted in the establishment of a broad framework for cooperation in the areas of oil, gas, coal, electric power generation, and energy efficiency, and resulted in the signing at the June 1992 Presidential summit of the Government-to-Government Agreement in Fuels and Energy. Subordinate Fossil Energy and Energy Efficiency Memorandums of Cooperation were signed by the Secretary and Minister of Fuels and Energy Shafanik in September and October 1993, respectively. Beyond scientific and technical cooperation, each initiative will provide for the involvement of the U.S. private sector in project planning and in defining potential commercial opportunities.

In November 1992, Freedom Support Act legislation was passed providing over \$600 million in support of the development of democratic institutions and free enterprise in the former Soviet Union. DOE received funds to support program efforts in both nuclear, and fuels and energy areas. Program design and implementation activities were carried out during 1993.

Japan

An important area of bilateral R&D cooperation is with Japan. The Department of Energy and predecessor organizations have a long history of cooperation with the Japanese Government, particularly in the area of advanced reactor research and other nuclear technologies. In 1979, the United States-Japan Energy Agreement expanded cooperation into several other fields, including fusion energy, high energy physics, synthetic fuels, and clean coal research. That same year, President Carter signed the United States-Japan Science and Technology Agreement, which served as an umbrella for cooperative efforts in basic research, with DOE participation primarily in the areas of neutron scattering and nuclear physics. The Science and Technology Agreement was renegotiated and signed by then-President Reagan and then-Prime Minister Takeshita at the Toronto Summit in 1988. The United States-Japan Energy Agreement was renewed in 1990.

The renegotiation of the Science and Technology Agreement secured Japanese commitment to seek balance in the technology exchange between Japan and the United States.

DOE continued to work with other cabinet agencies to develop cooperative research programs and to effect the assignment of our researchers to Japanese laboratories under the agreement. Although this agreement is important to overall United States-Japan relations, it has not had a significant effect on DOE cooperation with Japan; mutual access to one another's facilities and programs traditionally has been excellent.

DOE continued active bilateral cooperation with Japan in radioactive waste management, the decommissioning of nuclear facilities, and the development of safeguards technology. DOE contributed to the Radiation Effects Research Foundation, which is headquartered in Hiroshima with laboratories in both Hiroshima and Nagasaki. The objective of the Radiation Effects Research Foundation is "to conduct research and studies, for peaceful purposes, on the medical effects of radiation on humans with a view to contributing to the maintenance of the health and welfare of atomic bomb survivors and to the enhancement of the health of all mankind."

In addition to work done under international or bilateral agreements, DOE performed work for Japan and other nations under contract at DOE laboratories when it is determined by both the individual laboratories and DOE that the work is related to unique capabilities of the laboratories and will not interfere with DOE projects. DOE laboratories maintain several major work contracts with Japanese utility companies and government organizations.

Western Europe and Canada

During 1992 and 1993, DOE enjoyed a significant program of energy R&D cooperation with a number of major European countries including Canada, the Commission of the European Communities, England, France, Germany, and Italy. This program covered a variety of areas including nuclear energy, fossil energy, waste management, and renewable energy. During the past 4 years, under the leadership of the Department of State and with strong guidance from the Department of Commerce and the Office of the U.S. Trade Representative, the Department attempted to negotiate new intellectual property rights provisions to serve as a consistent set for all U.S. agencies. To date, these negotiations have not been successful. Hence, during this period no new agreements have been negotiated, and renewal of ongoing agreements, when desired by both sides, has either been approved for relatively short periods (less than 1 year) or held in abeyance. This has unfortunately slowed down or stopped some very beneficial cooperation. As of the end of 1993, it appeared that some progress was finally being made, and it is hoped that this problem will be solved during 1994.

It should be noted that cooperation on the International Thermonuclear Experimental Reactor involving the European Communities, Japan, Russia, and the United States was successfully launched with its own intellectual property rights provisions. This was done with the assistance and cooperation of the interested U.S. agencies in the agreement negotiation.

Republic of Korea

Areas of cooperation with the Republic of Korea include nuclear reactor safety, radioactive waste management, safeguards, nuclear spent-fuel management, coal technology, passive solar systems, and energy conservation. To date, more than 100 individual projects in more than 20 subject areas are under way under the auspices of the State Department-led Joint Standing Committee on Nuclear and Other Energy Technologies. In addition, three DOE laboratories continued to engage in energy technology cooperative activities with the respective research institutions of the Republic of Korea's Ministry of Science and Technology. These activities—including coal technology, solar energy, and energy conservation—will be transferred to the United States-Republic of Korea Science and Technology Agreement, under development by the Department of State, when it enters into force.

China

Under the United States-China Science and Technology Umbrella Agreement, initially concluded in 1979, there are 29 signed implementing protocols. DOE has three: high energy physics, nuclear physics and controlled magnetic fusion, and fossil energy.

In the high energy physics cooperative research areas, DOE helped plan, design, and develop China's first collider—the Beijing Electron Positron Collider—which operates at an energy level of about 5 billion electron volts. The collider, completed in 1988, is open to experimenters from the international high energy physics community.

In the magnetic fusion research area, DOE and the Chinese Academy of Science have continued joint experiments at the Institute of Plasma Physics in Hefei, China; Princeton University; the University of California at Berkeley; and the University of Texas.

In the fossil energy technology research area, five annexes to the implementing protocol have been signed to date, including cooperative activities on mine safety, coal preparation and beneficiation, coal combustion and utilization, and carbon dioxide-induced climate change. In the coal technology area, exchanges of engineers to examine the coal samples from both the United States and China have been conducted. In the carbon dioxide-induced

climate change study, joint field trips and experimental stations in western China have been established by the Chinese Government with DOE participation. Scientists from both countries are studying the effects of increasing atmospheric carbon dioxide from fossil fuel combustion and methane generation from rice paddies on a local, regional, and global basis. This joint effort provides opportunities for scientists to share information, leading to a better understanding of the earth-atmosphere climate system and to improved climate prediction.

State of Agreements

As of September 30, 1993, the Department was cooperating with 26 countries, including the European Communities, under 152 bilateral energy research and development agreements and annexes. Most of these agreements are with Canada, France, Germany, Japan, and the United Kingdom. Table 20-3 lists currently active agreements.

In radioactive waste management, cooperation continued with Belgium, Canada, the European Communities,

Table 20-3—Bilateral energy research and development agreements in effect as of September 30, 1993

Country	Science technology or research and development in general	Technical information	Nuclear fission	Fusion and high energy physics	Fossil energy	Renewables, conservation, and other
Australia	1	1	1	0	1	1
Belgium	0	0	1	0	0	0
Brazil	0	0	0	0	1	2
Canada	1	2	2	1	7	0
Chile	0	0	0	0	1	0
China	0	0	0	4	3	0
Costa Rica	0	0	0	0	1	0
European Communities	0	0	2	7	0	2
Germany	0	0	5	0	0	0
Finland	1	1	0	0	0	0
France	0	0	11	0	0	0
Italy	1	0	0	0	0	0
Japan	2	0	28	16	1	7
Mexico	1	0	0	0	0	1
The Netherlands	0	1	0	0	0	0
Norway	0	1	0	0	0	0
Poland	1	0	0	0	2	0
Russia	1	0	1	3	0	2
Saudi Arabia	0	0	0	0	0	2
South Korea	0	0	0	0	1	2
Spain	1	0	1	0	0	0
Sweden	0	1	3	0	0	0
Switzerland	0	0	4	0	0	0
United Kingdom	1	1	4	0	0	0
Yugoslavia	1	0	0	0	0	0
Venezuela	2	0	0	0	8	1
Total	14	8	63	31	26	20

Note: Principal agreements with Department of Energy involvement, listed by number in each principal subject or technical field. Many countries, such as Japan, have several agreements in each broad technical field, such as nuclear fission.

France, Germany, Japan, Russia, Sweden, Switzerland, and the United Kingdom. Joint work in nuclear fuel development continued with France, Japan, Switzerland, and the United Kingdom. Cooperation in safeguards and physical security of nuclear materials continued with France and Germany, as well as with the European Communities.

In fossil energy research, cooperation continued with Canada, China, France, India, Italy, Japan, Mexico, the Republic of Korea, the United Kingdom, and Venezuela. Cooperation in renewables or energy conservation continued with Australia, Israel, Italy, Japan, the Republic of Korea, and Saudi Arabia.

In fusion energy, work continued primarily with Canada, China, the European Communities, Japan, and Russia. In high energy physics, cooperation with China, Japan, Russia, and Western European countries continued. Programs to exchange technical information, bibliographic data, and abstracts of energy-related information continued with France, Germany, Israel, Italy, The Netherlands, the Nordic countries, and the United Kingdom.

Agreements Signed

Between October 1, 1992 and September 30, 1993, the Department entered into 10 new bilateral agreements and annexes, as shown below.

Australia:

Nuclear Material Control, Accountancy, Verification, Physical Protection, and Advanced Containment and Surveillance Technologies for International Safeguards Application

Brazil:

Cooperation With the State of Pernambuco in the Establishment of a Solar Energy-Based Rural Electrification Program

Cooperation With the State of Ceara in the Establishment of a Solar Energy-Based Rural Electrification Program

China:

Superconducting Super Collider

European Communities:

International Thermonuclear Experimental Reactor

France:

Liquid Metal Reactor/Fast Reactor Research and Development (Inactive)

Germany:

Annex to the Project Agreement in Nondestructive Assay Techniques and Instrumentation Liquid Metal Reactor/Fast Reactor Research and Development (Inactive)

Hungary:

Technical and Administrative Assistance

Japan:

Testing of Negative Ion Sources and Accelerators for Neutral Beam Injectors

International Thermonuclear Experimental Reactor

Conceptual Design and Prototype Detector Development of Fuel Pin Measurement Techniques for a Mixed Oxide Fuel Fabrication Facility

Video Motion Detection Authentication System for Plutonium Fuel Protection Facility (PFPP) Product Storage Area

Mass Transport: Characterization and Predictive Technologies

Poland:

Krakow Clean Fossil Fuels and Energy Efficiency

Russia:

Fuels and Energy

Superconducting Super Collider

International Thermonuclear Experimental Reactor

Saudi Arabia:

Assessment of Solar Radiation Resources

Spain:

Radioactive Waste Management

Sweden:

Site Characterization and Repository Performance

United Kingdom:

Liquid Metal Reactor/Fast Reactor Research and Development (Inactive)

Existing Bilateral Agreements

Extended in Force

The following list summarizes the bilateral agreements extended from October 1992:

Canada:

Radioactive Waste Management

Subsidiary Agreement No. 2 for a Radioactive Waste Management Technical Cooperation Program

European Communities:

Nuclear Materials Safeguards Research and Development

France:

High Energy Laser-Matter Interaction Physics

Japan:

Centralized Liquid Metal Fast Breeder Reactor Component Reliability Data Base and Data Base Management System

Cooperation in Doublet III Project

Annex I on Fundamental Studies of Irradiation Effects in Fusion Materials Utilizing Fission Reactors

Remote-Controlled Nondestructive Assay Safeguards
Techniques for Process Holdup in Plutonium Conversion
Development Facility

Nuclear Material Control and Accounting Measures for
Safeguards and Nonproliferation

Nordic Countries:

Exchange of Energy-Related Information (Denmark,
Finland, Norway, Sweden)

Venezuela:

Energy Research and Development

Existing Agreements and Annexes

Allowed to Lapse

Between October 1, 1992, and September 30, 1993, the
following existing agreements and annexes were allowed
to lapse (some may be restarted in the future):

Norway:

Fossil Energy—Enhanced Oil Recovery

Annex I—Absorption of Chemicals on Reservoir Rock

Annex II—Multitracer Technology Applied to Petro-
leum Reservoir Studies

Annex III—Development of a Geologic Reservoir Da-
tabase for Stochastic Modeling

France:

Remote Systems Technology

Radiation Hardening of Remote Maintenance Control
System Hardware for Applications of High Radiation Fields
Exchange of Energy Information

Germany:

Remote Systems Technology

Switzerland:

Nuclear Plant Life Extension Research

Israel:

Basic Energy Sciences Information/Personnel Exchange

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on Energy Facility Siting, August 1993.

CHAPTER 21

GENERAL COUNSEL

MANAGING ENERGY DEMAND

The Office of General Counsel (OGC) gave substantial legal advice and drafting help in support of the Department's programs and activities for managing energy demand. The main areas of this support during 1992 and 1993 follow.

Appliance Energy Efficiency Program

The National Appliance Energy Conservation Act establishes initial standards levels for most major household appliances; DOE must determine by rule whether to raise or retain the initial standards. During 1992 and 1993, DOE was preparing a major rulemaking involving eight of the covered product standards. A notice of proposed rulemaking was published in the *Federal Register* on March 4, 1994.

Legal work was completed on an advance notice of proposed rulemaking regarding the establishment of energy conservation standards for furnaces, central air conditioners, and refrigerators. This notice was published in the *Federal Register* on September 8, 1993.

OGC gave legal assistance in connection with applications by several small manufacturers seeking statutory 2-year exemptions from applicable standards.

The Appliance Energy Efficiency Program also establishes test procedures for covered products by rule. These test procedures govern determinations of product compliance with the applicable energy efficiency standards. The

test procedures also are the basis for information on Federal Trade Commission labels and in advertising. DOE published in the *Federal Register* on August 23, 1993, a notice on three proposed revised test procedures. DOE is drafting for publication in the *Federal Register* in early 1994 two notices on four proposed revised test procedures.

OGC provided legal work in connection with the review of and action upon 14 petitions for test procedure waivers submitted by affected manufacturers.

In 1992, OGC completed work on a notice setting forth updated representative average unit costs of energy for use in standardizing label and other information under the program. The Department published this notice in the *Federal Register* on January 5, 1993, with the data becoming effective on February 4, 1993, and remaining effective until further update.

State and Local Financial Assistance Programs

The State Energy Efficiency Programs Improvement Act of 1990 amended the authorities of three DOE state and local financial assistance programs: Weatherization Assistance for Low-Income Persons; State Energy Conservation Planning; and Retrofits for Schools and Hospitals. OGC gave substantial legal advice and drafting service in preparing the notices of final rulemaking that implement these statutory amendments. The State Energy Conservation Planning final rule was published on November 5, 1992 (57 FR 52942); the Weatherization Assistance for Low-Income Persons final rule on March 4, 1993 (58 FR 12514); and the Retrofits for Schools and Hospitals final

rule on February 19, 1993 (58 FR 9424). OGC is providing legal assistance in additional rulemaking activities to incorporate the further amendments to these programs made by the Energy Policy Act of 1992 (EPACT) (Public Law 102-468). EPACT, which was enacted October 24, 1992, also repealed the Energy Extension Service, a fourth DOE financial assistance program.

States, as fiduciaries, are spending billions of dollars in oil overcharge restitutionary funds, partly under the state and local financial assistance programs (Table 21-1). Orders and settlement agreements approved by the courts govern such funds and expenditures. A DOE committee reviews, approves or rejects, and monitors state use of the restitutionary funds through the guidance of the Stripper Well Committee. OGC is an active member of that committee.

Energy Management in the Federal Sector

OGC supported DOE's coordinating and assisting roles regarding energy efficiency and the use of renewable energy in the Federal Government's buildings and general operations, pursuant to statute and Executive Order 12759. OGC also is providing assistance in drafting regulations that would establish procedures and methods under EPACT for use by all Federal agencies to acquire energy savings through performance contracting. A notice of proposed rulemaking was published in the *Federal Register* in the spring of 1994.

Table 21-1.—Restitutionary Payments for Conservation Programs (Oil overcharge funds distributed to states, territories, and possessions, as of September 30, 1993)

State	Totals	State	Totals
Alabama	\$70,228,117	Nebraska	36,096,268
Alaska	19,974,968	Nevada	19,299,563
American Samoa	1,136,217	New Hampshire	22,635,468
Arizona	46,289,495	New Jersey	165,424,376
Arkansas	56,906,926	New Mexico	30,779,505
California	415,549,935	New York	359,533,742
Colorado	53,713,225	Marianna Islands	693,171
Connecticut	76,902,749	North Carolina	101,330,302
Delaware	21,336,271	North Dakota	20,062,372
District of Columbia	11,454,647	Ohio	183,501,466
Florida	203,490,481	Oklahoma	58,916,961
Georgia	101,138,847	Oregon	47,092,149
Guam	6,495,274	Pennsylvania	222,054,380
Hawaii	30,738,845	Puerto Rico	47,174,128
Idaho	20,997,817	Rhode Island	19,007,785
Illinois	221,248,579	South Carolina	53,872,783
Indiana	116,580,828	South Dakota	19,020,004
Iowa	64,605,404	Tennessee	76,486,545
Kansas	56,087,514	Texas	330,670,899
Kentucky	62,220,407	Trust Territories	118,576
Louisiana	108,398,586	Utah	29,257,749
Maine	36,210,630	Vermont	12,563,215
Maryland	80,945,628	Virgin Islands	20,401,965
Massachusetts	155,644,526	Virginia	114,443,382
Michigan	169,942,747	Washington	74,275,646
Minnesota	90,047,759	West Virginia	30,487,664
Mississippi	61,106,149	Wisconsin	88,072,465
Missouri	94,405,813	Wyoming	19,486,963
Montana	23,047,503	Totals	\$4,679,605,380

RENEWABLE ENERGY

During 1992 and 1993, OGC gave legal advice and drafting help in support of the Department's renewable energy programs and activities.

Basic Research and Development

The Department conducts extensive research and development in renewable energy technology areas, such as wind; biomass (including alternative fuels feedstocks); ocean thermal; and photovoltaic cells and other solar technologies. OGC helps prepare various related *Federal Register* notices and provides other legal services as needed.

The Department submitted to Congress legislation that OGC drafted to sell two Alaskan Federal hydroelectric projects and terminate the Alaska Power Administration. Representative Young introduced the legislation as H.R. 5516.

FOSSIL ENERGY

Clean Coal Technology

During 1992, OGC continued to help the Clean Coal Technology Demonstration Program negotiate cooperative agreements in connection with the fourth round of the program. In addition, OGC gave legal advice and counsel to the Office of Fossil Energy (FE) in the development of the program opportunity notice for the fifth round of the Clean Coal Technology Demonstration Program. OGC was counsel to the Source Evaluation Board in the evaluation and selection of proposals, which occurred in 1992, and is providing legal support to FE in the negotiation process.

Naval Petroleum and Oil Shale Reserves

In 1992, OGC continued to provide extensive legal support for the activities of the Naval Petroleum and Oil Shale Reserves, including sales of crude oil, natural gas, and natural gas liquids; gas gathering contracts; and

communitization and operating agreements to implement the Naval Oil Shale Reserves Oil and Gas Protection Program. OGC's responsibilities cover all legal activities associated with the Headquarters Office of the Naval Petroleum and Oil Shale Reserves and the program's two field offices, one in Bakersfield, California, which manages and operates the Government's interests in Naval Petroleum Reserve No. 1 (Elk Hills, California) and No. 2 (Buena Vista Hills, California); and a field office in Casper, Wyoming, which manages and operates the Government's interests in Naval Petroleum Reserve No. 3 (Teapot Dome, Natrona County, Wyoming), and Naval Oil Shale Reserves Nos. 1 (Colorado), 2 (Utah), and 3 (Colorado). OGC also helped in connection with the Department's consideration of legislative initiatives to authorize the divestiture through leasing of Naval Petroleum Reserve No. 1, the sale of Naval Petroleum Reserve No. 3, and the leasing of mineral interests on the Naval Oil Shale Reserves in Colorado for natural gas production. OGC also gave legal support in connection with the Department's decision to transfer to the Strategic Petroleum Reserve (SPR) 20,000 barrels per day (2,740 metric tons per day) of crude oil from Naval Petroleum Reserve No. 1 from June 1, 1992, through March 31, 1993. OGC helped FE develop a new pricing provision with a price adjustment factor for sales of natural gas produced from the Naval Petroleum and Oil Shale Reserves. Finally, OGC represented the Department in a number of contract disputes before the Energy Board of Contract Appeals arising from sales of crude oil from Naval Petroleum Reserve No. 1 and helped the Department of Justice defend cases before the U.S. Court of Claims and the U.S. Court of Appeals for the Federal Circuit.

Strategic Petroleum Reserve

In 1992, OGC continued to give extensive legal support to the Headquarters Office of SPR, which gives management and policy guidance to SPR's Project Management Office in New Orleans, Louisiana. The Project Management Office in turn operates the six SPR oil storage sites located along the gulf coast of Texas and Louisiana. The major areas in which OGC gave legal support in 1992 were oil acquisition strategies and solicitation activities; storage facility development; and drawdown and distribution procedures. OGC participated in analyzing new legislative requirements relating to the expansion of SPR storage capacity and oil fill to 1 billion barrels (137 million metric tons). In this connection, the office supported ef-

forts to fulfill the requirement of the Energy Policy and Conservation Act Amendments of 1990 to submit to Congress an amendment to the Strategic Petroleum Reserve Plan detailing DOE's plans for the design, construction, and acquisition of storage facilities to achieve SPR storage capacity of 1 billion barrels (137 million metric tons). OGC also provided advice and support in connection with the sale of the decommissioned SPR site at Sulphur Mines, Louisiana.

Electricity Exports and Presidential Permits for Border Electricity Facilities

In 1992, OGC gave legal support to FE in connection with the issuance of authorizations for the export of electricity from the United States to Canada and Mexico pursuant to section 202(e) of the Federal Power Act. OGC also helped FE evaluate and issue Presidential permits for the construction of facilities at the borders of the United States for the export and import of electricity, pursuant to Executive Order 10485, as amended by Executive Order 12038. With respect to the Presidential permitting process, OGC helped FE to determine the reliability impacts associated with installing international electric transmission lines and importing electricity and to assess the environmental impacts associated with the construction of international electric transmission lines. OGC also provided support in the Department's participation in international consultations pertaining to electricity trade.

During 1992 and 1993, OGC continued to advise FE on the issuance of natural gas import and export authorizations, including implementation of a provision in EPACT that expedites authorization of certain import and export activities. EPACT amended the Natural Gas Act to eliminate the Department's public interest finding for imports and exports of natural gas with countries with which the United States has a free-trade agreement, and for imports of liquefied natural gas generally. This amendment affects the U.S. gas trade with Canada, which comprised two-thirds of the 1992 applications, and trade with Mexico, since approval of the North American Free Trade Agreement (NAFTA) by Congress in November 1993.

DOE orders approving the export by Yukon Pacific Corporation of liquefied natural gas from the North Slope of Alaska to the Pacific Rim by means of the Trans-Alaska Gas System are being challenged by Alaskan Northwest Natural Gas Transportation Company and Foothills Pipe Lines, Ltd. in the U.S. Court of Appeals for the D.C. Cir-

cuit. The court issued an order in May 1991 holding the case in abeyance pending disposition of related filings at the Federal Energy Regulatory Commission (FERC). In an order issued in May 1993, the court asked DOE to file status reports on the FERC filings at 30-day intervals. FERC public hearings were held in June 1993 in Alaska, and written comments were submitted in July. A second petition filed in the D.C. Circuit involved review of minor technical amendments to the *Brooklyn Union, et al.* (Iroquois pipeline) import authorization; it was denied in October 1992.

Office of the Federal Inspector for the Alaska Natural Gas Transportation System

In 1992, OGC drafted legislation to abolish the position of the Federal Inspector for the Alaska Natural Gas Transportation System (ANGTS) to support the 1993 budget. EPACT contains legislation to accomplish this purpose; it abolished the Office of the Federal Inspector and transferred its functions and authorities to the Secretary of Energy. During 1992 and 1993, OGC continued to give advice on ANGTS-related matters, primarily to FE, which is performing the functions of the former Federal Inspector on an informal basis. For example, the Northern Pipeline Agency, the Office of the Federal Inspector's Canadian counterpart, periodically requested comments on pipeline procurement issues in connection with expansion of the ANGTS prebuild in Canada.

Natural Gas

In 1992 and 1993, OGC provided legal support for the Department's natural gas policy activities in general and the impact of state gas regulation in particular. OGC formulated and articulated the Department's position on state regulation of natural-gas production prorationing, in response to congressional proposals to limit state discretion. DOE opposed the legislation and supported the states' traditional power to regulate gas production to conserve resources, protect correlative rights, and prevent waste. In addition, OGC contributed to drafts of the Natural Gas Strategic Plan in April 1992; gave legal advice to the Office of Domestic and International Energy Policy (now, Office of Policy, Planning, and Program Evaluation) on the Department's Notice of Inquiry on State Natural Gas

Regulation and the draft Domestic Natural Gas and Oil Initiative; and was involved with efforts to forge a closer working relationship with state regulators through cooperation with the National Association of Regulatory Utility Commissioners.

OGC advised FE on recommendations to the U.S. Internal Revenue Service concerning proposed regulations defining eligibility for a tax credit for enhanced oil recovery projects. OGC gave general support to the Department on FERC matters, including the FERC Order 636 restructuring rule and the Gas Research Institute funding mechanism. OGC also provided legal support for the Department's policy on natural gas matters of international significance, including the nature of the U.S. commitment to Canada on ANGTS and the ongoing trade dispute between the California Public Utility Commission and the Canadian provinces of Alberta and British Columbia.

OGC gave legal support to FE regarding Outer Continental Shelf leasing matters, coastal zone consistency appeals, reports to Congress required by the Powerplant and Industrial Fuel Use Act, the operation and issuance of coal capability "self-certifications" and exemptions under the Powerplant and Industrial Fuel Use Act, and FE's regulatory review program.

NUCLEAR ENERGY

Advanced Reactor Research and Development

In 1992, OGC gave extensive legal support and help to the Office of Nuclear Energy (NE) on administrative and legislative initiatives, as follows:

1. Fostered the development and commercialization of advanced reactors, including various advanced light-water reactors, the liquid metal reactor, and the modular high-temperature gas-cooled reactor
2. Assessed the liquid metal reactor technology's potential for use in recycling light-water reactor actinide wastes
3. Assessed and responded to legislation that would have converted the Fast Flux Test Facility (a liquid metal reactor) to an internationally supported, multimission research and development center.

Isotope Production and Distribution Program

OGC provided legal support to NE's Isotope Production and Distribution Office in the following ways:

1. Developed arrangements preparatory to DOE's reentry into the production of enriched radioisotopes of molybdenum, iodine, and phosphorus, critical to U.S. nuclear-medicine research and clinical practice
2. Considered and responded to requests of private companies that DOE withdraw from competitive, commercial isotope markets supplied by the private sector.

Nuclear Free Zone Litigation

In *United States v. City of Oakland* (Ninth Circuit), an action in which DOE and the Navy successfully challenged the constitutionality of the city's Nuclear Free Zone Ordinance, the court dismissed Nuclear Free Oakland's appeal for lack of jurisdiction on the ground that Nuclear Free Oakland had not timely appealed the district court's denial of its motion to intervene.

ENVIRONMENTAL RESTORATION AND WASTE MANAGEMENT

Environmental Compliance Agreements

OGC participated in the negotiation of a number of environmental compliance agreements with the Environmental Protection Agency (EPA) and the states. These agreements set forth the procedures and schedules under which the Department of Energy will comply with the provisions of various Federal environmental laws at its facilities, including the Comprehensive Environmental Response, Compensation, and Liability Act; the Resource Conservation and Recovery Act (RCRA); the Toxic Substances Control Act; the Clean Air Act; and applicable state laws. Environmental compliance agreements were executed or negotiated for many DOE facilities, includ-

ing the West Valley Demonstration Project; the Lawrence Livermore National Laboratory; the Grand Junction Project Office (uranium mill tailings cleanup in Grand Junction, Colorado); the Savannah River Site; and the Mound Laboratory.

Waste Management

OGC provided legal support for the Department's efforts to explain to congressional staff the need for continued storage of mixed waste at DOE facilities pending development of treatment technology and capacity. The provisions of the Federal Facility Compliance Act of 1992, enacted on October 6, 1992, reflected this need. OGC also provided support to the Department's activities related to used oil and its recycling and reuse as a fuel.

Environmental Restoration and Waste Management Programmatic Environmental Impact Statement

OGC supported the Department in its public meetings about the draft Implementation Plan for the Environmental Restoration and Waste Management Programmatic Environmental Impact Statement, and participated in several meetings with EPA and the Council on Environmental Quality to discuss the evolving scope of the Programmatic Environmental Impact Statement.

Waste Isolation Pilot Plant

OGC worked closely with the Office of the Assistant Secretary for Congressional and Intergovernmental Affairs, the Office of the Assistant Secretary for Environmental Restoration and Waste Management, and congressional committees to enact legislation that withdrew Federal land and provided for testing of the Waste Isolation Pilot Plant (WIPP) (Public Law 102-579).

In *State of New Mexico v. Watkins* (Circuit Court for the District of Columbia), a consolidated Federal Land Policy and Management Act, the National Environmental Policy Act (NEPA), and RCRA action in which the State of New Mexico and several environmental groups filed suit against DOE and the Department of the Interior to

enjoin the introduction of transuranic waste to WIPP in Carlsbad, New Mexico, the court of appeals reversed the district court's ruling that WIPP cannot qualify for interim status under RCRA. However, it affirmed the district court's ruling that the Secretary of the Interior exceeded his authority under the Federal Land Policy and Management Act by extending the existing WIPP land withdrawal order and modifying the purpose of the withdrawal to permit the WIPP test phase, and thus upheld the injunction ordered by the district court. Subsequent to the circuit court's decision, Congress passed a legislative land withdrawal approving the introduction of transuranic waste to WIPP for testing purposes, assuming all other legal requirements are met.

Nuclear Safety

OGC provided legal support for a broad range of activities concerning nuclear safety and, in particular, supported rulemaking proceedings to implement the civil penalties provisions of the Price-Anderson Act Amendments of 1988 and to codify DOE's nuclear safety requirements. Proposed 10 Code of Federal Regulations (CFR) Part 820 would set forth the procedures for imposing and contesting civil penalties. Proposed 10 CFR part 830 would set forth the safety requirements for managing DOE's nuclear facilities. Proposed 10 CFR parts 834 and 835 would set forth the safety requirements for protecting the public, facility workers, and the environment from exposure to radiation. OGC also helped draft the DOE Radiological Control Manual issued in June 1992.

CIVILIAN RADIOACTIVE WASTE MANAGEMENT

In 1992, OGC continued to give legal assistance to the Office of Civilian Radioactive Waste Management concerning all aspects of its mission under the Nuclear Waste Policy Act of 1982, as amended. That mission includes the responsibility to locate, characterize, construct, and operate a permanent geologic site for the disposal of spent nuclear fuel from civilian nuclear power reactors and high-level radioactive waste resulting from the Nation's defense activities in a manner that protects public health and safety and the environment. The activities conducted by OGC to assist in this mission include the following:

1. Help in preparing a license application to be submitted to the Nuclear Regulatory Commission for the construction and operation of a repository and a monitored retrievable storage facility
2. Preparation of documents and review of correspondence to Congress, the Nuclear Regulatory Commission, the states, and other stakeholders and members of the public concerning program activities and legal issues, such as whether the Department has a legal obligation under the Nuclear Waste Policy Act to begin spent-fuel acceptance in 1998 and the extent of the Department's authority to conduct site-characterization activities
3. Legal analysis concerning financial assistance, such as payments equal to taxes to eligible jurisdictions, under the Nuclear Waste Policy Act and grants to jurisdictions to study the feasibility of hosting a monitored retrievable storage facility
4. Review of environmental, health, and safety statutes, and state permitting requirements relevant to site characterization at Yucca Mountain, Nevada, such as water appropriation permits that were granted in 1992 from the Nevada State Engineer

In *State of New York v. United States* (Supreme Court), a case in which the state sought a declaratory judgment that the Low Level Radioactive Waste Policy Act Amendments of 1985 is unconstitutional, the Supreme Court held invalid under the Tenth Amendment the provision of the act requiring states to "take title" to wastes generated within their borders by 1996. However, the Court upheld the validity of the remainder of the act, including the monetary and access incentives that are designed to encourage states to provide low-level radioactive waste disposal facilities.

POWER MARKETING AND ENERGY PRODUCTION

Uranium Enrichment

In 1992, OGC helped NE's Office of Uranium Enrichment participate in an antidumping proceeding directed against imports of uranium and enriched uranium from the Commonwealth of Independent States (states of the former Soviet Union) and draft the terms of an agreement to suspend the ongoing antidumping investigation.

OGC also assisted NE in developing a government-to-government agreement with Russia that would provide for the purchase by the United States of highly enriched uranium produced in Russia, the conversion of the material, and the resale to U.S. utility customers as low-enriched product. OGC is helping NE negotiate the contract terms for the purchase of Russian material in both the highly enriched and low-enriched forms.

In addition, OGC helped implement that part of EPACT that provides for the establishment of a separate government corporation for the U.S. enrichment enterprise. This included participation in interagency efforts to resolve critical problems associated with budgetary, environmental, labor, safeguards, and health and safety requirements that are addressed by the legislation.

DEFENSE PROGRAMS

Workforce Assistance

In 1992, OGC drafted a bill to give help to workers and their communities affected by a change in the mission of a DOE nuclear defense facility that was introduced by Senator Brown as Senate bill 2483. The office also drafted amendments to this bill and to other legislation on this subject. Related provisions were enacted as part of the National Defense Authorization Act for Fiscal Year 1993 (Public Law 102-484).

Reconfiguration of the Defense Complex: Programmatic Environmental Impact Statement

During 1992 and 1993, OGC supported the Department of Energy in its ongoing preparation of the Reconfiguration Programmatic Environmental Impact Statement for the nuclear weapons complex. The office reviewed the Programmatic Environmental Impact Statement Implementation Plan (published in February 1992). OGC also concurred in the distribution of the Nonnuclear Consolidation Environmental Assessment to affected states and Indian tribes for preapproval review in December.

ENERGY RESEARCH

High Energy Physics

In 1992, OGC provided legal advice on the funding of operations and planning for potential future construction and operations at the Stanford Linear Accelerator Center and the Fermi National Accelerator Laboratory.

Superconducting Super Collider Program

In 1992, OGC provided legal advice on funding of construction and magnet development for the Superconducting Super Collider (SSC) Program.

Nuclear Physics— New Facilities

In 1992, OGC provided legal advice on the funding of continued construction for the Continuous Electron Beam Accelerator Facility and the Relativistic Heavy Ion Collider at Brookhaven National Laboratory.

Basic Energy Sciences and Education

In 1992, OGC gave legal advice and help to the DOE Science and Technology Advisor, the Office of Energy Research, and the Energy Systems Acquisition Advisory Board on Basic Energy Sciences and Education initiatives, including the following:

1. Critical technologies and advanced materials
2. High-temperature superconductivity
3. Science, mathematics, and engineering education
4. Funding for construction of the Advanced Neutron Source, a user facility to be located at Oak Ridge National Laboratory
5. Funding and planning for the completion of construction of the Advanced Light Source at Lawrence Berkeley Laboratory and the Advanced Photon Source at Argonne National Laboratory

FUSION ENERGY

Fusion Energy Policy

In 1992, OGC provided legal services in support of the Office of Energy Research's budget requests, congressional oversight activities, and administrative initiatives in the Fusion Energy Program including preparatory to further scientific studies using the Tokamak Fusion Test Reactor at Princeton Plasma Physics Laboratory; U.S. participation in the engineering design activities for the International Thermonuclear Experiment; and the development of a Tokamak Physics Experiment to study advanced tokamak operating modes and extend the tokamak concept to the steady-state regime.

LABORATORY MANAGEMENT SUPPORT

National Laboratories

In 1992, OGC gave legal support and help to the Science and Technology Advisor regarding the operations of the DOE national laboratories, including the following:

1. Resolution of issues involving laboratories' performance of non-DOE Work for Others, as provided for in the Atomic Energy Act
2. Conclusion of a memorandum of understanding with the National Institutes of Health on biomedical research grants to DOE laboratories
3. Interfacing with the Nuclear Regulatory Commission

Technology Transfer

OGC manages the Department's intellectual property program. In that capacity, the office plays an integral role as legal adviser in all technology transfer agreements and activities, as well as in the identification and protection of intellectual property for commercialization by the private sector. In 1992, OGC gave drafting assistance for technology transfer legislation that passed the Senate, and the office also drafted technology transfer provisions that became part of EPACT. In 1993, OGC helped prepare the

Strategic Plan for Partnerships for Global Competitiveness and various resulting technology transfer process improvements, including the new Modular Cooperative Research and Development Agreement. The office also helped draft provisions for the proposed new Work for Others Agreement with the private sector.

INTELLIGENCE AND NATIONAL SECURITY

Emergency Preparedness

In 1992, OGC gave legal assistance to the Office of Emergency Planning and Operations (OE) in connection with a wide range of energy emergency preparedness issues and programs, including the use of energy industry "voluntary agreements" authorized by 1991 amendments to the Defense Production Act of 1950 (DPA); the use of the energy industry Executive Reserve Program under the DPA; the use of DPA priority contracting assistance authority; the availability of statutory waivers of the Jones Act and other coastwise laws to alleviate existing or impending fuel shortages; DOE's Continuity of Government Program; and the application of the Disaster Relief Act. OGC also gave advice to OE in the preparation of the study required by EPACT of the unique vulnerabilities of the Nation's insular areas (Virgin Islands, Puerto Rico, Guam, American Samoa, Palau, and the Commonwealth of the Northern Mariana Islands) to oil supply disruptions. OGC also provided legal support to OE in its participation in the International Energy Agency's (IEA) Seventh Allocation Systems Test held in November 1992. OGC supported OE in its efforts to respond to natural disasters during 1992-93, including Hurricane Hugo and the Mississippi River Flood.

ADMINISTERING ENERGY LAWS AND REGULATIONS

Rulemaking Activities

Procedural Review

OGC ensures that all offices involved in rulemaking comply with general administrative law requirements under the

Administrative Procedure Act (APA) and Department of Energy Organization Act. Support includes review of various rulemaking documents and discussion of procedural alternatives and strategies. This workload grew substantially during 1992 because of increased DOE rulemaking responsibilities and other causes.

NEPA Compliance Procedures

Reflecting the initiatives announced in Secretary of Energy Notice 15-90, in 1990, OGC helped draft a notice of final rulemaking to modify and issue as regulations existing DOE guidelines for complying with NEPA.

Nuclear Safety Standards

In 1992, OGC gave advice on procedural requirements of APA and the Department of Energy Organization Act regarding development of several nuclear safety rules. In late 1991, DOE had published the first three of these proposals for public comment. In 1992, OGC gave legal assistance on finalization of two of these nuclear safety rulemakings; a notice of final rulemaking to establish procedural rules regarding civil penalties for nuclear safety violations in DOE nuclear activities (this notice was resubmitted to OMB on February 26, 1993 and had been pending at OMB on January 20, 1993); and a notice of final rulemaking to establish DOE's standards for occupational radiation protection for workers at its facilities (this notice was resubmitted to OMB in May 1993).

Substance Abuse

In 1992, OGC gave advice on sufficiency of rulemaking regarding drug and alcohol abuse regulations applicable to employees of DOE contractors. The Department published the notice of final rulemaking regarding drug abuse (part 707 rules) in the *Federal Register* on July 22, 1992 (57 FR 32652). On the same day, DOE proposed adding provisions to part 707 relating to misuse and abuse of alcohol by contractor employees in health- and safety-sensitive positions. An interim final rule adding the alcohol-related provisions to part 707 has been submitted to OMB for its review and publication in the *Federal Register*.

DOE Orders Task Force

Two court cases have invalidated provisions in DOE orders, holding that the policies in those provisions were rules requiring promulgation through notice-and-comment

rulemaking under APA. There are likely to be similar substantive situations in the future. OGC is helping the DOE Office of Administration and Management interpret these adverse court decisions as the Department decides how to revise the DOE order system.

“Whistleblower” Protection

Employees of contractors performing work at DOE facilities should be able to provide information without fear of reprisal to DOE, Congress, and certain contractors concerning violations of law, health, and safety, or matters involving gross mismanagement, waste, fraud, or abuse. In 1992, OGC substantially contributed to the development of a procedure for investigation, hearing, and review of allegations of reprisal for such disclosures. The final rule establishing DOE’s “whistleblower” protection program was published in the *Federal Register* on March 3, 1992 (57 FR 7533), effective April 2, 1992.

Worldwide Nuclear Powerplant Safety

In 1992, OGC helped draft and clear a notice of proposed rulemaking intended to expedite safety-related assistance by U.S. firms to civilian nuclear powerplants worldwide. The proposal was published in the *Federal Register* for public comment on March 11, 1993 (58 FR 13427).

Implementation of the Major Fraud Act

In 1992, OGC helped with the rulemaking to implement the Major Fraud Act of 1988 with regard to the unallowability of management-and-operating contractor costs incurred in connection with criminal, civil, or administrative proceedings and to otherwise limit DOE reimbursements of such costs to 80 percent of the contractor’s incurred costs. After issuance of a proposed rule and consideration of public comments, DOE is developing the final rule.

Procurement

In 1992, OGC gave legal support to the Department’s multibillion dollar procurement, financial assistance, and financial incentives activities. These efforts involved all of the Department’s major programs, including particularly the development and production of nuclear weapons and weapon systems; environmental research, develop-

ment, and restoration activities at DOE facilities and sites; nuclear waste disposal; and basic and applied energy research and development efforts at privately owned facilities and at Government-owned, contractor-operated facilities, such as the national laboratories. OGC gave legal support in connection with proposal evaluation and contractor selection, contract administration, and bid protest and contract dispute representation.

In support of the Department’s contract reform initiative, which was announced in May 1993, OGC provided extensive legal support to the Contract Reform Team in their development and analysis of contracting issues. The Contract Reform Team is conducting a comprehensive review of the Department’s contracting mechanisms and practices, and is responsible for developing specific administrative, financial, and legislative improvements to help reform the system.

OGC played a significant role in providing guidance about the implementation and interpretation of procurement regulations to ensure that the Department’s contractors responsible for managing and operating its facilities are held financially accountable for their performance, most notably in the environment, health, and safety areas. OGC also gave legal support to the Office of Environmental Restoration and Waste Management in the ongoing development of new contracting concepts and mechanisms for the cleanup of DOE sites where nuclear weapons were developed and produced.

OGC provided substantial support in DOE’s negotiations with the University of California, which resulted in new contracts for it to manage and operate the Lawrence Berkeley Laboratory, the Lawrence Livermore National Laboratory, and the Los Alamos National Laboratory. These contracts substantially revised the relationship that had existed between the University of California and DOE for nearly 50 years. Under the new contracts, the university will be more accountable for its performance and more responsive to DOE’s requirements.

Included among the major contractor selection boards for which OGC provided legal advice is the board established to select a new contractor to manage and operate Sandia National Laboratories. OGC also gave legal advice to numerous boards established to consider whether the Government’s best interests would be served by extending an existing contract with a particular management and operating contractor, or by selecting a new management and operating contractor. Two significant determinations were to extend the contract with Westinghouse Electric Corporation to manage and operate the Bettis Atomic Power Laboratory and to extend the contract with

Reynolds Electrical and Engineering Company to manage and operate the Nevada Test Site.

Standards of Conduct

In 1992 and 1993, OGC continued to administer DOE's Standards of Conduct Program. This effort is designed to ensure departmentwide compliance with statutes and regulations covering, among other things, employee disclosure of financial interests, prohibited holdings, restrictions on political activities, and prohibitions regarding post-DOE employment activities. In addition, OGC helped nominees for positions filled by Presidential appointment with conflict-of-interest requirements associated with the nomination process. Further, OGC prepared ethics training plans for calendar years 1993 and 1994 and forwarded the plans to the Office of Government Ethics, pursuant to the requirements of section 301 of Executive Order 12674 and 5 CFR part 2638 that each executive branch agency establish a program of ethics training to ensure that employees are aware of Federal statutes, regulations, and Executive orders relating to ethics matters. As of September 30, 1993, more than 3,000 DOE Headquarters employees had attended annual training.

Regulatory Oversight

In 1992 and 1993, OGC administered the Department's implementation of Presidential directives on reducing the burden of Government regulation. This regulatory review program required a review of existing regulations and programs with the objectives of identifying and removing unnecessary burdens on the private sector and of fostering economic growth. OGC drafted the notice of inquiry that appeared in the *Federal Register* in March 1992 requesting public comment on the existing regulations identified by DOE as potential candidates for revision or elimination. Based on suggestions received during the public comment period and on DOE's own further analysis, DOE determined to rescind 13 DOE regulations and to revise 3 others. In this regard, OGC played a major role in drafting the many necessary *Federal Register* notices and securing timely compliance with the Presidential publication schedule. The regulatory review program also imposed a moratorium on issuing new proposed or final regulations except those believed to satisfy one or more

of the program's "exceptions" criteria. OGC substantially assisted DOE in implementing this aspect of the program as well.

In 1992 and 1993, OGC coordinated Office of Management and Budget-interagency clearance of DOE proposed and final rules under Executive Order 12291. This office reviewed almost all DOE notices as to suitability for *Federal Register* publication. OGC also advised on the preparation of regulatory impact analyses of major rules under Executive Order 12291.

During the reporting period, OGC prepared DOE's regulatory agendas for April and October 1992 and 1993 pursuant to Executive Order 12291 and— with PO— prepared DOE's 1992 and 1993 Regulatory Programs pursuant to Executive Order 12498. The semiannual regulatory agendas explain to the public DOE's current rulemaking activities and plans. The annual Regulatory Program describes current departmental regulatory policy and significant regulatory activities.

On September 30, 1993, President Clinton issued Executive Order 12866, "Regulatory Planning and Review," which revoked Executive Orders 12291 and 12498 and somewhat altered their requirements. Under the new Executive order, the General Counsel serves as the Department's regulatory policy officer, with the responsibility for coordinating the Department's implementation of the Executive order.

CONGRESSIONAL, INTERGOVERNMENTAL, AND INTERNATIONAL AFFAIRS

Legislative Support

During 1992, OGC gave substantial legal and drafting help in the development of EPACT, enacted October 24, 1992.

OGC also helped departmental efforts to analyze the various major bills related to the National Energy Strategy and to communicate with OMB and Congress about them. Once EPACT was enacted, OGC completed several important analytical documents concerning Department activities required by the new law. OGC also drafted and reviewed bills, bill reports, and testimony relating to energy conservation, renewable energy, regulatory reform, and numerous other issues affecting the Department.

To assist the new Administration, OGC prepared a report citing the legal bases for all the Department's activities and compiled a compendium of laws that affect the organization and operation of the Department.

In addition, OGC provided other legislative drafting services in the past 2 years to the Office of the Secretary and congressional committees, such as a provision to take the Nuclear Waste Fund off budget; amendments to the Federal Facilities Compliance Act (Public Law 102-386), which subjects Federal facilities to fines and penalties under certain Federal and state environmental laws; and amendments to the various technology transfer and Government laboratory bills considered by several House and Senate committees. OGC gave significant analytical help to the Office of the Secretary and the conference committees on the Defense Authorization Act for 1994 during consideration of that bill.

International Atomic Energy Agency

In 1992, OGC supported DOE's participation in the International Atomic Energy Agency (IAEA), playing a key role in drafting conventions on nuclear matters, especially nuclear safety. OGC had lead responsibility for efforts relating to revision of the Vienna Convention on Civil Liability for Nuclear Damage.

International Energy Agency

In 1992, OGC significantly supported DOE's participation in the activities of the International Energy Agency (IEA). OGC gave legal advice to DOE program offices about the operation of various IEA programs, particularly the IEA's Emergency Oil Sharing System, and about U.S. legal requirements for participation in IEA activities. OGC also played the lead role within the Government for implementing the Energy Policy and Conservation Act antitrust defense for U.S. oil companies participating in IEA. In this role, OGC had primary responsibility for the Government's antitrust monitoring of U.S. oil companies' participation in IEA's Seventh Allocation Systems Test (AST-7) conducted in November 1992. OGC prepared the Secretary's antitrust approval letter authorizing U.S. oil companies to participate in AST-7 and provided antitrust monitors for test activities involving oil company representatives at the IEA's offices in Paris. OGC made presentations on

the requirements of the Secretary's antitrust approval letter at IEA-sponsored training sessions for U.S. and foreign oil companies in Washington, D.C., and in Paris. In addition to these AST-7 activities, throughout 1992 the office also provided monitors for and maintained records of regular meetings of IEA industry advisory groups.

Trade and Investment Agreements

In 1992, OGC participated in and provided extensive drafting assistance and other legal support to the U.S. teams negotiating the energy and government procurement chapters of the North American Free Trade Agreement (NAFTA), which was signed by the U.S., Mexico, and Canada on December 17, 1992. OGC participated in DOE briefings for congressional staff on NAFTA energy issues. The office's representatives also participated in the inter-agency NAFTA "Lawyers Group" chaired by the Office of the U.S. Trade Representative, which was convened for the purpose of analyzing crosscutting legal issues that arose during the course of the approximately 15 months of NAFTA negotiations.

In 1992, OGC provided extensive legal support to DOE members of the U.S. delegation to the European Energy Charter Basic Agreement negotiations in Brussels. In December 1991, the United States and approximately 50 other countries (including all Organization for Economic Cooperation and Development members except New Zealand, and almost all of the Newly Independent States (NIS) in Eastern and Central Europe including Russia and other republics of the former Soviet Union) signed the European Energy Charter, a political declaration endorsing a framework for energy investment in NIS and ensuring access of NIS energy to the West. The charter committed signatories to seek to conclude a Basic Agreement, a binding energy-sector agreement covering trade, investment, the environment, and other matters. The European Energy Charter also contemplates protocols under the Basic Agreement on nuclear safety, energy efficiency, and hydrocarbons.

International Energy Research and Development Cooperation

In 1992, OGC gave extensive legal advice and drafting assistance to DOE offices in negotiating and concluding new international agreements for cooperative research and

development and science and technology activities, and in extending and amending existing agreements. During that year, DOE initiated a number of new international arrangements with the Russian Federation, the other republics of the former Soviet Union, and other Eastern and Central European countries; OGC provided extensive legal support for these initiatives.

OGC also participated in the drafting and negotiation of a new multiparty agreement on fusion energy with the European Atomic Energy Community, Japan, and the Russian Federation for a 6-year engineering design program for an International Thermonuclear Experimental Reactor (ITER). The agreement was signed in July 1992. OGC participated in meetings in Tokyo and Vienna of the Special Working Groups established by the ITER Council, which were convened to draft a protocol to the ITER Agreement detailing the technical objectives of the ITER engineering design program, to develop task assignment guidelines, and to establish procedures for assignment of scientists and other personnel to the ITER engineering sites located at San Diego, California; Garching, Germany; and Naka, Japan. OGC helped the Office of Energy Research successfully propose amendments to the U.S. visa regulations to permit foreign scientists assigned to the ITER site in San Diego, California, to extend their stay in the United States beyond the normal 3-year period to 6 years to complete the ITER engineering design program. OGC also worked with the U.S. Internal Revenue Service and tax agencies in Japan and Germany to determine the income tax liability of U.S. scientists working at the ITER sites in Germany and Japan and of foreign scientists assigned to the San Diego site. OGC also worked with the legal adviser to IAEA in Vienna to establish a joint fund at IAEA for use by the four ITER parties.

OGC also participated extensively in the drafting and negotiation in Russia of an international agreement between DOE and the Russian Federation Ministry of Atomic Energy for a program of collaboration on the SSC, which was signed by Russia in December 1992 and by the Secretary of Energy in Washington, D.C., in January 1993. OGC also provided drafting assistance on an SSC collaboration agreement between DOE and the Chinese Academy of Sciences, which was signed by the parties in November 1992 in Beijing.

OGC gave drafting assistance to a number of DOE offices in the development of new multilateral research and development agreements under the auspices of IEA. These included a proposed new IEA Implementing Agreement for the Establishment of the IEA International Centre for Gas Technology Information.

EXPORT ASSISTANCE

In 1992, OGC gave legal support to DOE's offices engaged in export promotion activities. OGC made presentations to DOE staff on statutory requirements pertaining to technology transfer and helped develop policies and programs to promote the export of U.S. energy goods, equipment, services, and technologies.

ENVIRONMENT, SAFETY, AND HEALTH

National Environmental Policy Act Support

OGC reviewed for legal sufficiency more than 100 environmental assessments and environmental impact statements; the office provided comments on them to the Office of Environment, Safety and Health. The review included a major effort in the preparation of the Sitewide Environmental Impact Statement and Record of Decision for the Lawrence Livermore National Laboratory and Sandia National Laboratory in Livermore, California.

OGC also provided legal support in the issuance of DOE's final regulations implementing NEPA (10 CFR part 1021). The office drafted major portions of the regulations and preamble, and gave substantial help to the Office of Environment, Safety and Health in determining how to respond to comments received on the draft regulations. OGC also helped amend the DOE order implementing NEPA to be consistent with the final regulations and helped prepare a delegation of authority to program offices to determine that an environmental assessment should be prepared for certain proposed actions.

Clean Air Act

OGC provided legal support regarding a number of activities conducted pursuant to the Clean Air Act Amendments of 1990. These included the NO_x Control Rule, the Environmental Protection Agency's Acid Rain Program, and the Grand Canyon Visibility Transport Commission. The office provided assistance in the preparation of departmental comments on a number of related rulemakings during 1992, including proposals on reformulated gasoline and state air toxics programs.

HUMAN RESOURCES AND ADMINISTRATION

Minority Bank Deposit Program

OGC drafted a legislative proposal to amend the Federal Deposit Insurance Act to allow the Department's Bank Deposit Financial Assistance Program for minority-owned banks to continue.

Regulatory Intervention

During the 2-year period covered by this report, OGC was involved in major administrative litigation in 11 jurisdictions on behalf of 15 DOE facilities and laboratories to ensure that the Department's utility rates are reasonable. DOE estimates the amount of pending utility rate increases affecting its facilities to be approximately \$8.4 million annually. Several of the proceedings involve important questions relating to reliability and adequacy of service to DOE facilities and consequently do not have an immediate dollar impact. During this period, 7 proceedings were concluded that will result in first-year savings to DOE facilities in the amount of approximately \$1.3 million.

Field Management

In *Phoenix Engineering, Inc. v. MK-Ferguson* (Sixth Circuit), an action seeking to enjoin the use of an alleged mandatory union hall referral system for work performed at Oak Ridge National Laboratory under a management and operating contract between DOE and MKO Ferguson, the court ruled that the project labor agreement does not violate the National Labor Relations Act or the Competition in Contracting Act, and affirmed the district court's dismissal of the case.

SPACE ACTIVITIES

Space Nuclear Power

OGC helped prepare budget requests to fund DOE's participation in the Space Exploration Initiative and the development and demonstration of space reactors and power

systems, for example, the SP-100 reactor in cooperation with the National Aeronautics and Space Administration. The office also directed legal efforts to authorizing the Air Force acquisition of Soviet Topaz thermionic space reactors for testing in U.S. laboratories for potential use in U.S. defense missions.

ECONOMIC REGULATORY ADMINISTRATION

The Economic Regulatory Administration was established in October 1977, in accordance with the Department of Energy Organization Act and was given responsibility for administering an array of regulatory programs, the foremost of which was the Emergency Petroleum Allocation Act of 1973. This act was the basis for the oil pricing and allocation regulations that governed the petroleum industry from October 1973 until decontrol in January 1981. Over the course of the program over 100,000 petroleum firms were audited.

The Economic Regulatory Administration reached its peak size in 1981, with an operating budget of \$160 million and nearly 2,000 employees working at Headquarters and at more than 100 field offices. For the year ending September 30, 1993, it had a staff of 60, one field office, and an operating budget of \$7.9 million. Approximately 40 cases remained unresolved and were either in administrative litigation before the Office of Hearings and Appeals and the Federal Energy Regulatory Commission or in judicial litigation before the Federal courts. As part of the Secretary's April 1993 departmental realignment, the Economic Regulatory Administration was made part of the Office of General Counsel.

The Economic Regulatory Administration has prevailed in some of the largest settlements in U.S. history. Notable among these are *Exxon* (1986), for \$2.1 billion; *Stripper Well* (1986), for approximately \$2 billion; and *Texaco* (1988), for \$1.25 billion. The successful settlement of these cases was noteworthy beyond the dollar amounts involved. The settlement of the *Stripper Well* case, in particular, paved the way for a more expeditious method for making restitution in many other pending cases involving crude oil overcharges. As of September 30, 1993, the program had recovered \$8.6 billion. Of this amount, the Department disbursed \$8.4 billion in restitutionary payments as follows: \$4.7 billion to the states for conservation programs (see Figure 21-1), \$1.8 billion to injured parties, and \$1.9 billion to the Federal Treasury.

21-1. Restitutionary funds distributed as of September 30, 1993.

CHAPTER 22

HEARINGS AND APPEALS

The Office of Hearings and Appeals is the focus of DOE's adjudicatory and appellate activities. The office carries out a broad range of activities related to DOE programs and regulations, and it analyzes and decides applications for exception from DOE regulatory requirements. In addition, orders of the Department (other than those issued by the Federal Energy Regulatory Commission) generally are appealable to the Office of Hearings and Appeals. The office adjudicates enforcement cases involving prior DOE price and allocation regulations and decides disputes concerning payments-equal-to-taxes determinations made in connection with DOE high-level radioactive waste and spent nuclear fuel repository sites.

Of note during the period October 1, 1991, through September 30, 1993, was the resolution by the Office of Hearings and Appeals of more than 21,000 applications for refund of oil overcharges filed by individuals; corporations; and Federal, state, and local government entities. As a result, refunds and other distributions totaling approximately \$112 million were paid during this period. In addition, the Office directed \$574 million in oil overcharge

funds to the states and Federal Government for use in lieu of appropriated funds. These refunds were drawn from moneys deposited with DOE in settlement of various compliance proceedings, and they represented restitution for injuries resulting from alleged violations of the prior mandatory petroleum allocation and price regulations.

Summaries of final decisions are published in the *Federal Register*, where notice also is given of new case filings. During this period, in addition to written decisions on approximately 21,000 refund applications and related matters, the Office of Hearings and Appeals issued more than 300 determinations in connection with Appeals, Applications for Exception, Remedial Orders, and other matters, many of which are subject to appeal to either a Federal court or the Federal Energy Regulatory Commission.

Appendix C lists all submissions received and determinations issued by the Office of Hearings and Appeals during the period October 1, 1991, through September 30, 1993, regarding private grievances and redress operations required under section 21 of the Federal Energy Administration Act of 1974 (Public Law 93-275).

CHAPTER 23

INSPECTOR GENERAL

PERFORMANCE EVALUATIONS AND REVIEWS

During 1992–93, the Office of Inspector General (OIG) conducted performance evaluations of departmental programs and operations and helped the Department’s management to identify a need for and to improve management controls. OIG also performed work mandated by law, including reviews required by the Chief Financial Officers Act of 1990, the Federal Managers’ Financial Integrity Act of 1982, and Office of Management and Budget Circulars A–128 and A–133.

AUDIT REPORTS

During 1992–93, OIG issued 321 audit reports. As a result, DOE management committed to taking corrective actions that OIG estimates will result in a more efficient use of funds totaling \$411.2 million. For reports issued during 1992–93, OIG made recommendations that could result in \$808.8 million being put to better use when DOE management implements them.

INVESTIGATIONS

OIG investigations of wrongdoing led to 22 criminal convictions, 127 case referrals to management for corrective action, and 70 administrative disciplinary actions. The

investigations also resulted in fines and recoveries of \$26,821,262.

REVIEWS OF OPERATIONS OFFICE MANAGEMENT SYSTEMS

OIG inspectors continued reviewing the efficiency and effectiveness of DOE operations office management systems by concluding a general management inspection of the DOE Nevada Operations Office. This resource-intensive inspection culminated in the issuance of a major report that contains 177 recommendations to improve the Nevada Operations Office’s and the Department’s management controls used in the administration of management and operating contracts. Many of the recommendations address safety and health, contract management, safeguards and security, and quality assurance issues.

REVIEWS OF ADMINISTRATION OF MANAGEMENT AND OPERATING CONTRACTS

Because the Department accomplishes its mission through the assistance of the management and operating contractors that run DOE’s major facilities, much of the 1992–93 OIG activity involved reviews and evaluations of the Department’s administration of the management and operating contracts. OIG also evaluated internal audit

functions and internal controls used by the Department's contractors to ensure that the costs claimed are allowable under contract.

SEMIANNUAL REPORTS TO CONGRESS

The Office of Inspector General issued four semiannual reports to Congress that list all audit and inspection reports issued during 1992–93. Additionally, the semiannual reports contain narratives that summarize significant audit, inspection, and investigative results that were achieved during each 6-month reporting period.

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CHAPTER 24

FIELD MANAGEMENT

INTRODUCTION

The Office of the Associate Deputy Secretary for Field Management was established by the Secretary in June 1993 to provide a more streamlined and mission-oriented departmental structure. This new office centralizes responsibility for strategic planning, management coordination, and oversight of the field operations in general and specifically of field execution of programs and projects accomplished through the eight multipurpose operations offices located in San Francisco, California; Idaho Falls, Idaho; Chicago, Illinois; Las Vegas, Nevada; Albuquerque, New Mexico; Aiken, South Carolina; Oak Ridge, Tennessee; and Richland, Washington.

The mission of the Office of the Associate Deputy Secretary for Field Management is to ensure the overall effective execution of the Department's programs through a viable, cost-effective, and energy-efficient field structure with adequate resources. This office also ensures cost-effective planning, acquisition, and management of departmental projects and facilities.

As a result of the realignment, the policy and oversight functions that formerly resided in the Office of Procurement, Assistance and Program Management and the Office of Administration and Management were consolidated under the new Office of Field Management. In addition, this office will continue to implement the Department's Contractor Employee Protection Program.

The activities and accomplishments reported in the following paragraphs cover the entire reporting period for each of these offices prior to consolidation. Accomplishments of the operations offices during the period covered by this annual report are included in the individual program office chapters.

FACILITIES MANAGEMENT

Facilities and Real Property Management

In 1992, the Department continued refinement of earlier initiatives designed to promote a comprehensive, corporate facilities strategy. DOE's philosophy is that facilities and related infrastructure are a central part of what is needed to accomplish changing departmental missions. The Department further believes that proper planning, acquisition, management, and disposal of corporate facilities are essential to the cost-effective accomplishment of those missions.

An important aspect of corporate facilities management is a thorough understanding of the existing condition of the Department's facilities. In 1992, the Office of Administration and Management (now Human Resources and Administration) issued the Capital Asset Management Process Directive, which institutionalized the management of the Department's buildings and other structures and facilities. The three critical elements of the process are the Condition Assessment Survey, used to determine the condition of the Department's facilities and to record those findings in a data base; a risk-based prioritization system that permits objective ranking of deficiencies identified in the Condition Assessment Survey; and Life Cycle Planning, which provides management with data for making asset management decisions. These decisions are then summarized annually in the site Capital Asset Management Process Report.

The Office of Associate Deputy Secretary for Field Management has a continuing mission to educate and increase professionalism in the facilities program. To further this mission, the office developed technical training courses in capital asset management, maintenance management, and site development planning, as well as videotapes for quick dissemination of critical material affecting capital asset management, site development planning, and maintenance management initiatives. Also in 1992, the Department established the Real Estate Certification Program to enhance the Department's ability to manage its real estate assets. Finally, DOE Headquarters facilities enhanced the solid waste management and multimaterials recycling program to include plastics and polystyrene.

In 1992, DOE completed major building maintenance improvements at Headquarters. Contractors completed the Forrestal Plaza deck renovation project in June 1992, and refurbished the Independence Avenue sidewalk by January 1993. The completion of these two projects should eliminate any further water infiltration and resultant building damage.

In January 1993, DOE began to replace the aluminum electrical feeders at the Forrestal building with copper feeders. The retrofit was completed in July 1993. In addition, contractors began the standby diesel generator upgrade project in July 1992, and the base contract was completed on December 31, 1992. This system will provide emergency power to critical areas at Headquarters. Contractors repaired roads and parking lots at the Germantown complex and installed three sets of automatic operating access doors.

Utilities Management

During 1992, departmental facilities and sites consumed 32.8 million megawatthours (118.1 gigajoules) of electric power, at a total cost of \$741.6 million and an average cost of 2.3¢ per kilowatthour (\$0.83 per megajoule), excluding settlement payments to the Tennessee Valley Authority. DOE consumed 18.5 billion cubic feet (0.52 billion cubic meters) of natural gas during 1992 at a cost of \$34.7 million, which includes the amount purchased and the amount produced at no cost as a byproduct and then consumed at the Naval Petroleum Reserve sites.

The average unit cost of purchased natural gas in 1992 was \$2.85 per thousand cubic feet (\$100.65 per thousand cubic meters). Recognizing the advantages of its large purchasing power, the Department approached the Defense Logistics Agency about DOE sites joining its Direct Sup-

ply Natural Gas Program. This program consolidates major Federal natural gas requirements and competitively awards supply contracts. Thirteen DOE sites are participating in the Defense Logistics Agency program, which results in savings of about \$8 million annually. Also, as a consumer, DOE participates in Federal and state utility regulatory proceedings when the proceedings are expected to adversely affect the Department. From 1984 to 1993, DOE has saved approximately \$95 million as a result of the Department's involvement in regulatory proceedings.

In-House Energy Management

The goals of the Department are to ensure that DOE sites and facilities decrease building energy consumption per square foot (square meter) by 10 percent in 1995 and 20 percent in the year 2000 compared with the 1985 base; to increase industrial facilities energy efficiency by 20 percent in 2000 compared with the 1985 base; and to decrease gasoline and diesel use in vehicles by 10 percent in 1995 compared with 1991.

In 1992, DOE decreased buildings energy consumption per square foot (square meter) by 21 percent from a 1985 base and industrial facilities energy consumption per square foot (square meter) by 30 percent from the 1985 base.

In response to the goals, from 1977 through 1992, the In-House Energy Management Program has funded 935 projects costing \$246.9 million. The projects have an annual savings of 31.7 trillion British thermal units (33.4 trillion kilojoules), equating to \$92 million in savings. In 1992, the program funded 68 projects for \$17.7 million. These projects have an annual savings of 1.7 trillion British thermal units (1.8 trillion kilojoules), equating to \$5.0 million. Additionally, from 1978 through 1992, the program funded \$35.7 million in surveys and studies to evaluate the technical feasibility and cost-effectiveness of various actions to improve energy efficiency in existing buildings and industrial facilities. During 1992, the program funded 75 surveys and studies totaling \$3.6 million.

On July 7, 1992, DOE held its official ground-breaking ceremony for the Energy Child Development Center in Germantown, Maryland. The Department designed the Energy Child Development Center using the most recent energy conservation techniques available, such as photovoltaics, solar hot water heating, energy-efficient lighting, low-E (argon gas filled) windows, and an energy management control system. DOE officially opened the center on September 8, 1992.

During 1993, the Office of Associate Deputy Secretary for Field Management undertook or assisted several maintenance and energy reduction initiatives, including the Shared Energy Savings Lighting Retrofit Project, which will reduce in the Forrestal building energy used to produce light by at least 60 percent. This project involves installing more than 33,000 energy-efficient fluorescent ballasts and tubes in the Forrestal building, with the entire cost of this retrofit being paid by the shared savings contractor. The shared energy savings contractor will recoup his investment by being paid a percentage of the savings over the 7-year contract term. The installation began on March 11, 1993, and was completed by August 31, 1993.

DOE contractors are currently working to convert the three oil-fired steam boiler burners at the Germantown heating plant to a dual-fuel, natural gas- (primary) and oil- (secondary) fired steam boiler burner system. In addition, the Department will upgrade the system to incorporate state-of-the-art technology and to meet current safety codes and regulations. DOE awarded the contract on November 1, 1992, and expects completion in 1994.

In October 1992, contractors began to install an energy Management Control System at the Forrestal building. The installation was completed in March 1993. DOE is currently installing an Energy Management Control System at the Germantown complex. The start date of the Germantown project was August 26, 1992, and it is scheduled for completion on March 19, 1994. These two systems use state-of-the-art technology to operate and monitor facilities equipment for optimum energy efficiency.

PROGRAM AND PROJECT MANAGEMENT

The following Program and Project Management Division initiatives continued in 1993:

1. The division extended the independent cost-estimating reviews to cover total project cost in addition to construction cost to give the acquisition executive a better understanding of the resources being committed to each major system acquisition. The division achieved an estimated savings or cost avoidance of approximately \$100 million.
2. The division brought approximately 25 major system acquisitions before the Energy System Acquisition Advisory Board to approve project baselines and approve or disapprove key decisions to proceed to the next phase of the projects.
3. The Division restructured the Energy System Acquisition Advisory Board to reflect the Secretary's realignment of the Department and to increase the involvement of stakeholders.
4. The division developed a new data base that would provide a concise report of projects to the acquisition executive. The report provides data on the cost, schedule, and scope, as well as on the project status. The system will continue to be improved as needs change.
5. The division developed a number of guides to help program and project managers and to maintain uniformity in preparing project documentation, cost estimates, and Energy System Acquisition Advisory Board actions. These have been instrumental in reducing duplication of effort at Headquarters and in the Operations Office.

Goals established for 1994 are to improve and simplify existing processes, reduce the burden on the field for the validation effort, and reorganize to meet the changing needs of the Department.

POLICY AND MANAGEMENT SYSTEMS SUPPORT

During 1992, the Department of Energy operations offices began the process of implementing a new Project Control System. A key provision is delegation of responsibility and authority to the field where the work is performed, with project managers accountable for bringing their projects in on time and within costs.

The Project Control System reflects Administration policy direction toward increased efficiency and cost effectiveness in Government. It is a result-oriented system that replaces the more narrowly focused and contract-oriented Cost/Schedule Control Criteria.

The system uses commercial principles and is designed to maximize controls at lowest costs to the Government. The system employs a risk-based graded approach to the application of controls that permits DOE to customize controls for specific projects. It is designed not only to decrease management systems control costs, but also to increase control of DOE projects. The operations offices expect significant savings.

The Project Control System is viewed as a significant improvement in departmental management systems by the

Office of Management and Budget, the General Accounting Office, other agencies (for example, the Department of Defense), and external associations.

In January 1993, DOE published *DOE 4700.4 Project Manager Certification* to establish certification requirements for DOE project managers at identifiable skill levels and to accelerate development of project managers. Minimum uniform performance standards for project managers were also issued. DOE signed partnership agreements with Human Resources and Atlantic Management Center Incorporated to design, develop, and deliver a new project management training curriculum within the DOE Professional Skills Training Program. Prototypes for the Project Management Overview and Project Control System courses were held in August 1993 and September 1993, respectively.

BUSINESS MANAGEMENT REVIEW

The Business Management Review Division continued to develop and implement a process to help the secretarial officers, operations office managers, and departmental contractors assess and improve the adequacy of management systems used to plan, budget, and control activities. This process is based on the approach of continuous improvement through self-assessment, lessons learned, and corrections of deficiencies.

The Division also assisted departmental managers in conducting Business Management reviews at the Richland Operations Office and the Rocky Flats Office.

CONTRACTOR EMPLOYEE PROTECTION

On March 3, 1992, the Department published in the *Federal Register*, part 708, title 10, Code of Federal Regulations, "Criteria and Procedures for DOE Contractor Employee Protection Program," which became effective on April 2, 1992. This rule establishes the Department's program to protect employees of its contractors and subcontractors who allege that they have been retaliated against for disclosing information evidencing a violation of law, rule, or regulation; environmental, safety, or health problems; or waste, fraud, abuse, or mismanagement. The Office of Contractor Employee Protection is charged with the responsibility for implementing part 708.

DOE developed the Contractor Employee Protection Program in response to concerns that contractor and subcontractor employees were experiencing employment reprisal as a result of coming forward with good faith beliefs that there were health, safety, and management problems at DOE facilities. These concerns have attracted considerable congressional and media attention. The Secretary's December 20, 1991, report to the President, required by the Federal Manager's Financial Integrity Act, identified the lack of such a program as a material weakness.

The responsibilities of the Office of Contractor Employee Protection include investigation and adjudication of complaints, oversight of field activities relating to contractor employee protection, and coordination with employee concerns programs. Part 708 provides protection for over 150,000 contractor and subcontractor employees. The Office of Contractor Employee Protection acts as the central point of contact for questions, concerns, or formal complaints raised by such employees relating to activities at DOE-owned or -leased facilities. Investigators, working closely with adjudicators, carefully review each complaint to identify issues. Efforts are made to resolve the matter informally. Failing such resolution, an investigator will be assigned responsibility to thoroughly investigate the complaint, interview witnesses, and obtain necessary documentary and other evidence. A report of investigation is developed as well as a proposed disposition, which contains findings of fact and conclusions. Either party to the case may request a hearing before the Office of Hearings and Appeals. If neither party requests a hearing, the Director of the Office of Contractor Employee Protection issues the agency decision. Decisions issued either by the Director, Office of Contractor Employee Protection, or the Director, Office of Hearings and Appeals, may be appealed to the Secretary or her designee. The office coordinates all requests for reviews and appeals with the appropriate departmental organization.

Since April 1992, employees have filed more than 65 cases with the Office of Contractor Employee Protection. Investigators have conducted approximately 24 onsite investigations, and the office has issued or is currently preparing proposed dispositions in these cases. In addition, several settlement agreements have been reached, resolving the complaints prior to investigation and adjudication. The office is working closely with the field and operations offices to encourage informal settlement of complaints. In October 1992, a training conference took place with field and Headquarters representatives discussing the Contractor Employee Protection Program. The Office of Contractor Employee Protection placed special emphasis on achieving informal resolution of cases, with training

in mediation techniques. The office arranged for additional mediation and dispute resolution training for DOE staff participants in June 1993, and some field and Headquarters staff have received intensive mediation training.

In addition, the Office of Contractor Employee Protection has developed and distributed to the operations offices a brochure for contractor and subcontractor employees that explains the availability of part 708 to individuals who believe they have been subject to reprisal for making

disclosures of waste, fraud, abuse, or mismanagement; or health, safety, or environmental concerns. The office has also developed and arranged for the posting of notices at DOE contractor-operated facilities advising covered employees of the protection afforded by the program. The office further developed an information package that provides detailed guidance for filing a complaint. This is intended to assist potential complainants in preparing a complaint under part 708.

CHAPTER 25

ECONOMIC IMPACT AND DIVERSITY

INTRODUCTION

The Office of Economic Impact and Diversity was created in June 1993 by combining the Office of Minority Economic Impact, the Office of Small and Disadvantaged Business Utilization, and the Office of Civil Rights. The new office's mission is to devise and lead diversity strategies that will ensure full participation of all employees and to create full partnerships with small and disadvantaged businesses and minority educational institutions. The office also provides oversight to the Secretary's Diversity Council, which works to promote excellence and equality in the Department's workforce, thereby creating and maintaining a positive work environment; to eliminate unlawful discrimination; to achieve equal opportunity and affirmative action; and to reflect and value at all levels, in all activities, and among all its contractors the diversity of American society.

MINORITY ECONOMIC IMPACT

The Office of Minority Economic Impact (MI) was established by section 211 of the Department of Energy Organization Act (42 U.S.C. 7141) to advise the Secretary about the effects of energy policies, regulations, and other departmental actions on minorities, minority educational institutions, and minority business enterprises and communities. The act also requires the Director of MI to inform the Secretary about specific ways to increase minority

participation in the Department's programs and procurement opportunities. To carry out its responsibilities, MI conducts a socioeconomic research and analysis program to determine the effects of national energy programs, policies, and regulations on minorities and minority communities; provides management and technical assistance to minority business enterprises, minority educational institutions, and minority communities; and provides financial assistance to minority business enterprises.

Socioeconomic Research and Analysis Program

The Socioeconomic Research and Analysis Program provides comparative socioeconomic data, policy and program impact analyses, and other information on minorities to DOE policy and program offices to assist with their impact assessments and legislative and regulatory actions, such as rulemaking proceedings. DOE is constantly developing and improving the program to accommodate quantitative methodologies and socioeconomic data by population and incorporating some of the analytical methodologies into software packages for use on personal computers. The program has focused on the following objectives: addressing the statutory requirements of section 211, developing analytical methods and related software that provide disaggregated energy-consumption data, and developing methods to address major departmental initiatives, integrated resource planning and demand-side management, and environmental concerns. The program

meets these objectives through the following three major tasks:

1. *Data base development and enhancement of analytical capabilities.* Under this task, energy socioeconomic assessment models are first developed through a comprehensive and systematic integration of detailed information from both national surveys (such as Energy Information Administration surveys, the census, and the Annual Housing Surveys) and the unique quantitative models developed by the program, and are then used to make disaggregated impact assessments and to forecast energy demand and expenditures by population categories, sectors, and regions. For example, the analysis developed for Figure 25-1 shows energy expenditures and share of income that households were projected to spend in 1992, disaggregated by various population groups and the U.S. census regions. These types of analyses enable the Department to develop more focused energy policies and programs and to more accurately forecast significant indicators of energy-consumption and -expenditure patterns.
2. *Policy assessments and related analyses.* The quantitative models developed by the program provide end users with analytical tools to determine the comparative effects of policies, programs, and so forth on socioeconomic groups; the composition of energy demand; the energy expenditure share of income; and the estimated residential and transportation energy consumption and expenditures of these socioeconomic groups. DOE also uses these same analytical methods to forecast the impact of specific energy policies and programs on the U.S. economy as a whole. Energy industry organizations use some segments of the analytical methodologies to determine least-cost planning activities and other energy policy and regulatory determinations.
3. *Technical market analysis and information.* The program uses its analytical methodologies and models to facilitate technical market analysis and projections for new energy products. DOE uses the models to determine significant factors such as market penetration indicators of new energy technologies, equity considerations, and cost-effectiveness. This type of information enables MI to provide focused

25-1. Projected energy expenditures by census region and population group, 1993. Source: Interpolated from data contained in Teotia, A.P.S., et al., *Minority Energy Assessment Report*, Argonne National Laboratory, ANL/ESD/TM-46, 1992.

technical assistance to its constituents, such as minority business enterprises and minority communities.

In 1992, the program focused on increasing MI's involvement in energy policy formulation and assessment by broadening its contribution to the data development and analysis efforts of the Department and the energy industry. With this focus, the major tasks in 1992 addressed programmatic needs of both the office and the National Energy Strategy. Some highlights are as follows:

1. At the June 1992 Symposium on SocioEconomic Research and Analysis Modeling, 75 public and private sector participants from the policy, research, and academic arenas indicated they had used these tools for energy demand forecasting, program evaluation, and other energy policy assessments.
2. Through this program, the office played a significant role in reviewing and assessing the impact of the National Energy Strategy on minorities, and, through the analytical capabilities of the Socioeconomic Research and Analysis Program, commented on the analysis used for developing the National Energy Strategy options.
3. The office initiated the development of a new, main-frame version of the Energy Policies Socioeconomic Assessment Model. This new version focuses on demand-side management and utility rate design analyses. Additionally, the office made a major effort to adjust and update estimation and validation devices in developing a public-use version of the utility rate design model.
4. The Socioeconomic Research and Analysis Program's Energy and Environment Assessment Project on differences in air pollution exposure was broadened by adding Asian and American Indian population categories, younger and older age groups, and the "disadvantaged" population group to the analytical comparisons. Subcounty analyses of exposure patterns for the Detroit and Houston metropolitan statistical areas were also included to extend the representation of the data and provide specific demographic information that would be significantly diluted by countywide analysis.
5. A series of share models was added to the main-frame model's analytical tool to assist local businesses and entrepreneurs in estimating the market potential for various kinds of energy conservation measures, technologies, and services. The share models, which are estimated by population group

and census region, provide initial characterization of energy consumption by type of fuel and end-use category.

6. The office sponsored numerous technical presentations at national conferences and analytical papers for publication in major professional journals to establish effective information-sharing networking for appropriate individuals and institutions interested in energy policy research methodologies and related energy issues.
7. The program initiated an American Indian Energy Data Analysis project to establish a comprehensive data base on socioeconomic energy use and related residential data for this ethnic population. The lack of this type of information makes it difficult to formulate sound policies, regulations, and programs for the American Indian population.

Minority Educational Activities

MI has continued to support educational growth in minority communities to increase the number of minorities in the sciences and energy-related fields through two distinct activities. First, MI has directly supported programs for minority educational institutions that aim to increase students' as well as faculty's pursuit and mastery of energy-related science and technology fields. Second, MI has served in an advisory role, through informal linkages, by:

1. Coordinating DOE-wide actions in support of Executive Order 12876 to strengthen the capacity of Historically Black Colleges and Universities to provide quality education and increase opportunities to participate in and benefit from Federal programs
2. Representing DOE in the planning, development, and implementation of the Federal programs sponsored by the White House Initiative on Historically Black Colleges and Universities

MI's direct support activities are in the form of annual financial support for programs directed at college-level minority students. This focus at the undergraduate level is consistent with that of the other offices within DOE, and was facilitated by Executive Order 12876, which established an annual goal for the amount of funds to be awarded in grants, contracts, and cooperative agreements to Historically Black Colleges and Universities. The fol-

lowing programs that make up MI's education portfolio have made a significant impact on the lives and careers of those young people who have been supported by these programs and on those institutions that have hosted these efforts. These programs are briefly described in the following paragraphs.

Historically Black Colleges and Universities Program

The Department continued to implement the Historically Black Colleges and Universities Program, which was developed under Executive Order 12876. The program seeks to strengthen the ability of Historically Black Colleges and Universities to engage in federally sponsored programs and to increase significantly the awards that the Department and its contractors make to these institutions. The Department's program calls for the active involvement of Historically Black Colleges and Universities in DOE's programming efforts. Moreover, it

seeks to have these colleges and universities represented on the Department's advisory committees and in national laboratory cooperative programs designed to provide faculty and students with research and training opportunities.

In 1992 and 1993, the Department continued to support the development and implementation of formal alliances, such as memoranda of understanding, among Historically Black Colleges and Universities and other minority institutions and DOE and its national laboratories. A comprehensive knowledge of science, mathematics, and engineering is essential for the Nation to continue its technological advances, and minorities have made progress in engineering. As shown in Table 25-1, the number of minorities enrolled in engineering from 1973-74 to 1992-93 has increased from 4.1 percent of the total to 12.6 percent of all students of engineering, as reported by the National Action Council for Minorities in Engineering. DOE programs and activities have had an indirect influence on this increase.

Table 25-1—Fall semester undergraduate enrollments in engineering, by academic year

Academic year	African American	Hispanic American	American Indian	Total minority	Total enrollment	Percentage minority
1973-74	4,869	2,371	204	7,444	183,520	4.1
1974-75	6,319	3,158	360	9,837	197,899	5.0
1975-76	8,258	3,941	317	12,516	228,183	5.5
1976-77	9,828	5,138	446	15,412	254,797	6.0
1977-78	11,388	5,944	618	17,950	286,500	6.3
1978-79	12,954	7,158	625	20,737	308,556	6.7
1979-80	14,786	8,454	759	23,999	337,807	7.1
1980-81	16,181	9,043	903	26,127	362,300	7.2
1981-82	17,611	10,200	970	28,781	384,162	7.5
1982-83	17,598	10,683	1,078	29,359	400,038	7.3
1983-84	17,817	11,599	1,127	30,543	402,561	7.6
1984-85	17,451	12,202	1,186	30,839	391,052	7.9
1985-86	17,994	12,941	1,120	32,055	379,830	8.4
1986-87	16,830	11,913	1,071	29,814	365,161	8.2
1987-88	17,300	12,981	1,136	31,417	352,848	8.9
1988-89	18,227	13,188	1,164	32,579	342,280	9.5
1989-90	18,939	13,761	1,205	33,905	334,723	10.1
1990-91	20,909	15,917	1,468	38,294	335,102	11.4
1991-92	21,891	16,374	1,538	39,803	335,585	11.9
1992-93	23,136	18,088	1,809	43,033	340,271	12.6

Note: Figures do not include the University of Puerto Rico.

Source: National Action Council for Minorities in Engineering.

Minority Educational Institution Assistance Program

The Minority Educational Institution Assistance Program consists of a number of interrelated activities that address the inadequate participation in Federal research at most minority educational institutions. The program includes the following activities to increase participation by minority educational institutions in major research programs undertaken by DOE:

1. *Infrastructure support.* Infrastructure support focuses on developing energy research capabilities, including proposal development and grants and contracts administration, through phased efforts designed to create self-sustaining centers at colleges and universities seeking to become research institutions in the sciences and technologies. In 1992, MI funded the testing of a model fellowship training program designed to enhance the capability of Historically Black Colleges and Universities and other minority educational institutions to establish comprehensive offices of sponsored research (research funded by the Federal Government or another industrial entity). The program is designed to increase the competitive skills of minority educational institutions by increasing their efforts in high-technology energy and environmental industrial activities; promote universitywide awareness that active research programs enhance the image and quality of their institutions; enhance minority institutions' chances for technology commercialization programs with the Department and other energy industry organizations; and train faculty on how best to tap into the Federal procurement process.
2. *Minority institutions research travel.* Under this program, faculty from minority institutions may apply for travel support to visit Government facilities, research institutions, industrial organizations, or other colleges and universities to discuss and plan energy-related research, including skills and techniques improvement, information exchange at conferences and seminars, and use of equipment and other resources.
3. *Minority undergraduate training for energy-related careers.* MI issued a notice of program interest in 1991 and selected projects to receive undergraduate support at 12 institutions with minority populations of at least 25 percent, including activities with high schools such as joint enrollment, summer studies, and some technical assistance. Examples of un-

dergraduate support include direct financial assistance, counseling and mentorships, undergraduate research experiences, enhanced curricula, and internships. In 1992, DOE provided continued funding to the 12 minority educational institutions that were awarded grants in 1991. Of this total, six awardees are Historically Black Colleges and Universities, four are predominantly Hispanic institutions, one is predominantly Asian, and one is predominantly American Indian.

Minority Honors Vocational Training and Industrial Assistance Program

The Minority Honors Vocational Training and Industrial Assistance Program provides energy-related training opportunities nationwide to financially needy minority honor students at selected 2-year postsecondary educational institutions. The program offers scholarships for tuition, books, tools, laboratory fees, and miscellaneous enrollment fees for energy programs. The program also helps participating schools to develop linkages with local energy industries. Only institutions with a minimum of four energy-related training programs are eligible to apply for grant funds under this program. MI is developing strategies to establish a formal structure for joint agreements linking the 2-year to the 4-year educational institutions, thereby ensuring program continuity and improving the potential for increased retention rates of students participating in the scientific disciplines.

Minority schools selected for participation must share a minimum of 50 percent of the program costs, directly or through in-kind contributions, and must incorporate all administrative and staff-support services required for tracking, monitoring, and reporting activities to promote industrial participation in the program. The program assisted 380 students in 1992 at the seven participating schools. Since its inception in 1987, more than 1,400 students have graduated from the program, over 1,150 have been placed in jobs, and more than 150 are continuing their education.

Cooperative Developmental Energy Program

The Cooperative Developmental Energy Program at Fort Valley State College in Fort Valley, Georgia, continues as a model for an innovative energy educational program with direct industry support. This program has received

nationwide recognition for establishing synergistic relationships among minority educational institutions and public and private organizations involved in high technology within the energy industry. From 1986 through 1992, more than 50 private energy industry organizations, DOE's Nevada and San Francisco field offices, and some of the national laboratories have funded approximately 90 percent of this program.

The program has implemented numerous energy-related curricula and seminars at Fort Valley. The two consortia implemented in 1991, geosciences and electrical engineering, were continued in 1992. Fort Valley State College signed these dual-consortium agreements to implement degree programs in geosciences (geology or physics) with the University of Oklahoma in Norman and in electrical engineering with the University of Nevada at Las Vegas. These consortia offer separate 2-plus-3-year degree programs with majority educational institutions (students take 2 years of study at their home colleges and 3 additional years at out-of-state colleges and graduate with specialties and dual bachelor's degrees in energy-related fields). Approximately 50 students receive full scholarships each year to participate in each consortium program.

Funding for the Geosciences Consortium for 1992 was provided by the Amoco Corporation, Atlantic Richfield Company, Chevron Corporation, Conoco Inc., Mobil Corporation, Oryx Energy Company, Phillips Petroleum Company, DOE's Office of Energy Research, and the National Science Foundation. DOE's Nevada and San Francisco field offices, the Bonneville Power Administration, the Bureau of Reclamation, Lawrence Livermore National Laboratory, and EG&G Energy Measurements Company have committed funds to the Electrical Engineering Consortium. Other electric utility companies and Federal Government agencies, including the National Science Foundation, provide support for the overall Cooperative Developmental Energy Program's summer internship, cooperative, job placement, and energy seminar program segments.

American Indian Technical Assistance Initiative

In 1992, DOE continued its special emphasis on programs to more effectively address American Indian communities' involvement in departmental programs. The American Indian Technical Assistance Initiative focused on the following areas:

1. *Information and resource identification.* MI continued to collect new information regarding the

number of American Indians attending undergraduate programs, their fields of study and major focus, and other pertinent information from the American Indian Graduate Center.

2. *Increased access to DOE programs.* In 1992, MI continued to provide information to American Indian communities regarding DOE programs, and DOE made a greater effort to include American Indian-controlled businesses in its programs. MI has generated significant interest in DOE programs through an intensive outreach program with national American Indian organizations. Consequently, numerous American Indian groups have contacted DOE program offices, including the Office of Environmental Restoration and Waste Management, the Office of Civilian Radioactive Waste Management, and the Office of Small and Disadvantaged Business Utilization, concerning procurement opportunities in which they could participate. Some associated projects are described in the Business and Community Development section of this chapter.
3. *Technical and program support.* With MI's assistance, other DOE offices also increased their support in 1992 for American Indian groups. Assistance projects to predominantly American Indian colleges increased, and both the Sandia and Lawrence Livermore National Laboratories increased their support to Bureau of Indian Affairs schools.
4. *Cooperative efforts with Federal and private sector offices.* MI improved the communication and working relationships among DOE and other Federal offices that serve American Indian communities. For example, the office cultivated a working relationship with the Department of the Interior's Office of Indian Education as well as its Economic Development Office. These efforts have focused on the availability of loan and grant funds to assist minority communities with energy-related projects. The office and its contractors also participate in a number of non-DOE national organizations, boards, and commissions.

Minority Energy Information Clearinghouse

MI maintains the Minority Energy Information Clearinghouse for the dissemination of information about energy programs and the impact of these programs on minority population groups, minority business enterprises, and

minority educational institutions. This management and technical assistance program supported its constituents, the programmatic activities developed by the office, and other departmental program areas in 1992 and 1993 by:

1. Providing a centralized repository for data generated by individual program areas within the office and other DOE program elements, in addition to relevant data and other information from the private sector of the energy industry
2. Facilitating data searches and providing specialized information to constituents and maintaining linkages with data bases in other Federal agencies
3. Preparing and publishing final reports, papers, conference proceedings, and brochures relating to programmatic actions of the office
4. Producing targeted mailings and periodical publications to disseminate program announcements and to support the overall functions of the office at conferences and so forth

The Minority Energy Information Clearinghouse also serves as a central source of information for inquiries from the private sector; the academic community; Federal, state, and local government; congressional staff; and DOE employees and contractors. The clearinghouse responds to hundreds of information requests each year (approximately 1,250 in 1993 from all sources).

In an effort to provide better service, a toll-free number for the Minority Impact Bulletin Board System provides 24-hour online computer access to selected clearinghouse information. Information available includes listings of minority educational institutions (that is, Historically Black Colleges and Universities, members of the American Indian Higher Education Consortium, and the Hispanic Association of Colleges and Universities and other minority educational institutions), DOE small and disadvantaged business contacts, a bibliography of publications of the Socioeconomic Research and Analysis Program, and selected technical references.

The clearinghouse also supports MI's Honors Training and Industrial Assistance Program through a microcomputer application system that allows participating institutions to input student data and generate required annual and quarterly reports and data files. The application software strips out personal (Privacy Act) identifiers for the individual students, thereby requiring no special handling of standardized reports and data.

In 1992, the clearinghouse updated its text and text-based graphic computer screens to support the Socioeconomic Research and Analysis Program. The screens, which

were designed by MI, give a brief overview of the program and show the role of the program's analytical models in the development and implementation of energy-related issues. The office combined approximately 50 screens within a presentation graphics package to produce two different slide shows that can be used with an overhead projector and display panel or with a stand-alone workstation. The shows can also be used as "electronic handouts" distributed to conference participants to provide background material, references, and contact information about the Socioeconomic Research and Analysis Program.

Business Development and Financial Assistance

Minority Business and Community Development

The Office of Minority Impact's Business and Community Development Program fulfills the mandated responsibilities set forth in Public Law 95-619, section 614, title VI, part 3. Specifically, the program is designed to provide management and technical assistance to enable minority business enterprises to participate in the Department's research, development, demonstration, and contract activities.

The primary objective of the program is to identify energy-related minority business enterprises and minority business opportunities that could benefit from the transfer of newly emerging technologies. Benefits include bringing economic growth, including the creation of new job opportunities and empowerment of community residents, to the communities in which the minority businesses and opportunities exist. Projects that include technical-manufacturing-assistance efforts in African American, Hispanic, and American Indian communities are emphasized. This objective is consistent with national efforts to develop minority businesses and to heighten the awareness of minority businesses as good investments toward the Nation's wealth and future.

The program is implemented by using a combination of the national laboratories and Historically Black Colleges and Universities. The national laboratories help minority businesses gain access to energy technology through information transmission, direct technical assistance, training, and facilitation of linkages with business assistance providers. Historically Black Colleges and Universities and other minority institutions offer professional, expert

human resources and help meet other workforce needs. They also develop research and analysis relative to the economic trends, marketing feasibility, and penetration of specific energy-related technologies.

The program is designed to provide a comprehensive range of services and support systems to minority-owned, energy-related businesses. These businesses are identified through various sources. Specific criteria are assessed as to their particular technical development needs to become successful ventures in the energy industry. The projects undertaken during 1992 included six minority-owned businesses. The sections that follow provide brief summaries of the minority business projects.

Cotton Insulation Manufacturing Project

In 1992, the Office of Minority Economic Impact completed an evaluation of the Cotton Insulation Manufacturing Project with the Gila River Indian Reservation south of Phoenix, Arizona. The findings revealed that cotton insulation products were comparable to fiberglass in thermal, acoustical, and flame retardation properties. They also were profitable as an insulation material. The cotton insulation process uses recycled cotton, including low-grade cotton, and other renewable resources. The product is attractive for its energy-saving and environmentally superior properties. It also has potential for adding manufacturing jobs and creating demand for cotton produced by minority-owned farms.

Mixed-Waste Separation Process Project

The Office of Economic Impact and Diversity developed a joint venture between a woman-owned biotechnology firm and a woman-owned high-technology firm to develop and test a proprietary foam-protein trap for capturing heavy metals. These firms used a filtration technology that was transferred to them through a license agreement from Sandia National Laboratories. The product provided an opportunity to study the high-level technology in the environmental and waste management area, which will ultimately result in the commercialization of this process.

Low-Head Hydroelectric Power Project

The Calista Corporation (an Alaska Native American Corporation), with the assistance of the Alaska Energy Authority, was the beneficiary of an environmental "Low-Head Hydroelectric" feasibility study that focused on the use of hydroelectric power in remote Alaskan villages. The project complements other Alaska Energy Authority

projects through reduced dependence on expensive diesel fuel and creates power-sharing opportunities between rural villages. If the study's recommendations are accepted, a \$5 million hydroelectric network would lower costs associated with diesel-fuel storage and use.

Electronic Chip Assembly Project

Lowe Manufacturing, Inc., an African American business enterprise in Dallas, Texas, is a defense- and aerospace-oriented manufacturer. They are providing printed circuit boards, designing integrated computer systems, and manufacturing guided missile parts, all of which would be enhanced by the transfer of chip-assembly knowledge. Sandia National Laboratories developed a chip for the Superconducting Super Collider project and used this project to train Lowe personnel in its assembly. As a result of the training, Lowe Manufacturing received a certification from Sandia for chip assembly.

Product Engineering and Marketing Study

A product engineering and marketing study to evaluate a solar photovoltaic manufacturing process was begun with Laguna Industries, a Native American Business located south of Albuquerque, New Mexico. In this pilot project, Sandia National Laboratories provided extensive information on photovoltaic technology to Laguna in the form of engineering requirements of the module manufacturing business and marketing analyses.

Solar Thermal Pilot Project

The Renewable Energy Commercialization Program addresses minority business selection for the transfer and commercialization of solar thermal technology. The objective of the Solar Thermal Pilot Project is to identify minority businesses interested in developing partnerships with the Sandia National Laboratory Solar Thermal Design Assistance Center.

Bank Deposit Financial Assistance Program

The Bank Deposit Financial Assistance Program helps increase the operating capital or deposit levels of minority-owned financial institutions through the purchase of \$95,000 certificates of deposit, thereby enhancing their potential to make loans and investments in the communities they serve. The program continued to coordinate with the Office of the Chief Financial Officer to ensure sound financial, analytical, and fiscal program constraints. The

source of all deposits for this program is the Department's Petroleum Pricing Violation Escrow Fund, which uses non-Federal funds. Administrative financial institutions acting as trustees for the Department provide trust services and manage program transactions for a reimbursement-of-cost fee.

In 1992, a total of 97 minority financial institutions participated in the program, with cumulative deposits of \$57 million, a significant increase over the 1991 level of \$25 million. In 1993, a total of \$182.5 million had been deposited in minority financial institutions nationwide, as shown in Figure 25-2. The program aims to achieve its optimum expansion of \$250 million by increasing the number of participating American Indian, Hispanic, African American, and women-owned financial institutions.

SMALL AND DISADVANTAGED BUSINESS UTILIZATION

The Office of Small and Disadvantaged Business Utilization is responsible for ensuring that a significant portion of DOE procurements is awarded annually to small businesses, disadvantaged businesses, labor-surplus-area firms, and women-owned businesses. This is primarily accomplished through total set-asides, partial set-asides, 8(a) sole source procurements, and 8(a) competitive procurements.

As a central point of contact, the office provides guidance and counselling to small business representatives and

coordinates small business policies and activities within DOE through a network of more than 100 small business-small disadvantaged business coordinators and specialists. These networks encompass DOE Headquarters, field locations, and various DOE contractor-operated plants and laboratory facilities.

Small Business Prime and Subcontract Awards

During 1992, the Department's contract awards to small business totaled more than \$3 billion (17.3 percent of DOE contracting). DOE prime contracts and management and operating (M&O) contracts were included in this sum.

During 1992, DOE awarded contracts totaling approximately \$307 million to small disadvantaged businesses under section 8(a) of the Small Business Act (Public Law 85-536 as amended). This total represents 1.7 percent of all prime contracts in excess of \$25,000 awarded by DOE during that period. During 1992, DOE and M&O awards to women-owned businesses and labor-surplus-area set-asides totaled \$327 million and \$597 million, respectively.

At the end of the third quarter of 1993, the Department's contract obligations to small businesses was \$332 million, including more than \$200 million to 8(a) firms and \$56 million to women-owned businesses.

The achievement in small, non-M&O subcontracting for 1992 was \$234 million, including \$23 million to disad-

25-2. 1993 deposits in the Department's Bank Deposit Financial Assistance Program.

vantaged businesses. These figures represent 49.9 percent and 4.8 percent of total non-M&O subcontracting, respectively.

Small Disadvantaged Business Subcontract Set-Asides

In June 1988, DOE published a regulation finalizing subcontracting initiatives begun in 1987. The regulation allows M&O contractors to set aside subcontracts for competition among small disadvantaged businesses. This practice resulted in \$80 million for subcontract awards to small disadvantaged businesses in 1990 and nearly \$121 million in 1991. In 1992, \$60 million was reported in M&O small disadvantaged business set-asides.

Procurement Highlights

Superconducting Super Collider

In 1992, the Superconducting Super Collider Laboratory awarded \$70.1 million in contracts to small disadvantaged and women-owned firms, \$26 million above its goal of \$44 million, and 10 percent of the annual Federal appropriation for the Superconducting Super Collider Laboratory Particle Accelerator.

Contracting and Subcontracting Opportunities

During 1993, DOE included subcontracting opportunities with M&O contractors, standard industrial classification codes, and size standards. DOE is the only agency that currently includes subcontracting opportunities in its forecast.

The 1993 forecast provided more than 600 contracting and subcontracting opportunities totaling \$1.6 billion. More than 6,000 copies of the forecast were distributed during 1993 by the Office of Small and Disadvantaged Business, program offices, Headquarters, and field contracting activities.

8(a) Pilot Program

In 1992, the office, in accordance with Department of Energy Acquisition Regulation 970.7104-12(F), developed and implemented a test 8(a) pilot program to increase M&O subcontract participation with small disadvantaged firms. The basic criteria for conduct of the program include: limitation of purchases to \$50,000 or less, restriction of eligi-

bility to 8(a) firms in the "developmental stage" (first 4 years), and authorization of M&O contractors to make noncompetitive awards to "developmental" firms at fair market prices (no premium to be paid).

Each quarter, participating M&O contractors submit reports to the Office of Small and Disadvantaged Business Utilization, identifying contracts that were awarded under the program during that quarter. The office is in the process of preparing a proposed rulemaking to make this a permanent program. In 1992, DOE M&O contractors awarded more than \$1.6 million to 8(a)-certified small disadvantaged firms through this program, and nearly \$4 million in 1993.

Technology Transfer

The National Competitiveness Technology Transfer Act of 1989 firmly established technology transfer as a mission of all Federal laboratories and facilities. The cooperative research and development agreement (CRADA) concept was created by the Federal Technology Transfer Act of 1986. A CRADA is a collaborative tool used by a company or university to gain access to government-owned-government-operated, government-owned-contractor-operated DOE laboratories, technologies, and expertise. Under these CRADAs, a DOE laboratory and one or more partners agree to collaborate, share costs, and pool the results from a particular research and development program. Agreements offer small businesses the following benefits:

1. Access to world-class technology
2. Potential for improved worldwide competitiveness
3. Less time between the research-and-development stage and commercialization
4. Shared intellectual property and protection of data for up to 5 years through special arrangements

During 1992, DOE's demonstrated commitment to working with and transferring technology to small and disadvantaged businesses produced numerous CRADAs, including

1. The Pittsburgh Energy Technology Center's Outreach Program through local and regional trade fairs
2. Los Alamos' involvement in 5 small business startups utilizing technology provided by DOE
3. Sandia National Laboratory's continued efforts with 6 to 10 small local businesses to commercialize DOE technology

As of September 1993, DOE had more than 621 CRADAs, 29 percent with small and minority businesses. The total value of the research for small and minority businesses is \$209 million, with private industry supplying in-kind and financial support equal to about 60 percent of the total.

Business Opportunity Development Reform Act

The Business Opportunity Development Reform Act of 1988 (Public Law 100-656) required that 10 Federal agencies, including DOE, conduct a Small Business Competitiveness Demonstration Program for 4 years beginning January 1, 1989. This program seeks to demonstrate whether the capabilities of small business firms in certain industry groups enable them to compete successfully on an unrestricted basis for Federal contracts. The program also attempts to determine whether the use of targeted goaling techniques can expand small business participation in areas where Federal contracting opportunities historically have been few despite adequate numbers of qualified small business contractors in the economy. Finally, the program seeks to determine whether expanded use of full and open competition adversely affects small business participation in certain industry groups.

The program initially suspended small business set-asides in four industries in which small businesses had obtained a disproportionately large share of Federal procurement contracts: construction, architectural engineering services, refuse systems and related services, and nonnuclear ship repair. To limit possible adverse impacts on small business participation in these industries, the program set a small business participation goal of 40 percent of total contract dollars in each of the four industries. Likewise, a 15-percent "emerging small business" (half the applicable size standard) participation goal was set aside for each of the groups. The 15-percent goal is included in the overall 40 percent goal. If quarterly reviews indicate a failure to reach the 40-percent goal within an industry, subsequent contracting opportunities will be solicited in the respective industry. The opportunities will reflect the excess of the amount reserved for emerging small businesses to attain the 40-percent goal for that industry through competition restricted to eligible small businesses.

During 1992, DOE awarded more than \$58 million in construction (representing 29 percent of total contract dollars in that category) and \$3 million in architectural engineering services (representing 1 percent of total con-

tract dollars in that category). Almost \$26 million of that amount went to emerging small businesses. The Office of Procurement, Assistance and Program Management and the Office of Small and Disadvantaged Business Utilization issued quarterly guidelines on instituting small business set-asides in all categories that did not attain the 40-percent goal for that industry. DOE awarded \$45,000 during 1992 to small businesses for refuse systems and related services.

Rural Area Business Enterprise Development Plan

In December 1989, pursuant to the provision of section 129 of Public Law 100-590, the Department of Energy established its Rural Area Business Enterprise Development Plan. The plan's objective is to foster DOE's continuing relationship with the small business community by expanding procurement and assistance opportunities to small rural-area businesses to meet the Department's mission of a comprehensive and balanced national energy plan. During 1992, DOE awarded 42 contracts totaling \$11.7 million and 16 project grants totaling \$907,000 to rural area small businesses.

DOE's heads of contracting activities, power administrations, project offices, and energy technology centers continue to inventory the rural-area small businesses in their locales. The Department is implementing outreach efforts to involve rural-area enterprises in meeting DOE's procurement and assistance requirements.

CIVIL RIGHTS

Affirmative Employment Programs

In recent years, the Department has recognized that women, minorities, and people with disabilities are significantly underrepresented within its work force. Moreover, DOE falls behind other Federal agencies of comparable size and mission in the representation of particular minority groups; and even greater disparities have been identified at the upper grade levels for women and most minority groups. White males occupy more than 70 percent of the Department's General Schedule/General Merit (Government pay classifications) GS/GM-13 through -15 posi-

tions, a percentage significantly disproportionate to their representation in the nationwide civilian labor force, which is 42.6 percent. At the senior executive service level, white males are dramatically overrepresented at 87.6 percent.

To address these problems, in mid-1992 the Department convened an Affirmative Employment Advisory Committee composed of senior-level managers from both Headquarters and the field. As a result, each departmental element prepared an action plan for the recruitment and advancement of minorities, women, and persons with disabilities. Each plan contained a workforce analysis of its Headquarters and field components that identified relevant underrepresentation and then developed action items to address the underrepresentation with strategies such as recruitment, promotion, and training. The plans were forwarded to the Office of Civil Rights for review and approval in the fall of 1992. Henceforth, the Office of Civil Rights will track the progress each organization makes toward implementation of their plan through a quarterly status report submitted by each organization.

The action plans are now in place, and the Office of Civil Rights is implementing them. Secretarial officers, managers, and supervisors are personally accountable for achievements in equal employment. The Offices of Personnel and Civil Rights will help managers and supervisors to identify recruitment sources that have the potential to add minorities, women, and persons with disabilities to the pool of candidates for their principal occupations. In addition, the Offices of Personnel and Civil Rights have encouraged all departmental elements to use special appointing authorities to hire persons with disabilities and disabled veterans. The Department set aside a pool of its full-time-equivalent slots for the sole purpose of hiring persons with disabilities under Schedule A authority.

The Department also strengthened the complaint processing system of its equal employment opportunity program during the latter half of 1992. DOE has eliminated the large backlog of cases pending investigation that existed during the first half of 1992 and has instituted processing timelines to prevent future backlogs. The Department has developed and issued an overall policy for processing complaints that delineates the various responsibilities of the Office of Civil Rights, the Program Secretarial Officers, and the field elements. DOE has refined and is using the automated complaint tracking system. It has developed procedures for investigations and given leadership and direction to the equal employment opportunity counseling program. The Department instituted new procedures for safeguarding the confidential information contained in the files of the Office of Civil Rights.

Finally, DOE has recently reiterated its commitment to the prevention of sexual harassment as a critical goal. In July 1992, the Department issued a Secretary of Energy Notice (SEN 32-92) on the prevention of sexual harassment to all employees. In addition, it developed a comprehensive departmentwide training program, with separate components for managers, supervisors, and employees, which began in January 1993. The Department also established a new sexual harassment telephone hotline to facilitate communication in this area.

APPENDIX A

EXPORT OF ENERGY RESOURCES BY FOREIGN COMPANIES

This appendix addresses foreign companies' exports of energy resources from the United States. Together with a separate annual report to Congress by the Economic Regulatory Administration, entitled *Electricity Exchanges Across International Borders*, which covers U.S. electricity trade, and the Energy Information Administration's *Profiles of Foreign Direct Investment in U.S. Energy 1988*, which covers foreign direct investment in U.S. energy sources and supplies, this appendix meets the reporting requirement of section 657, subpart 8, of the Department of Energy Organization.

U.S. laws and regulations control the export of crude oil, natural gas, and uranium by imposing licensing requirements on firms involved in such exports. To the best of the Department's knowledge, no foreign-owned or foreign-controlled companies exported natural gas or uranium during 1992 and 1993. Under existing export reporting requirements, it was impossible to determine to what extent brokers involved in the export of U.S. coal represented foreign entities.

CRUDE OIL AND REFINED PETROLEUM PRODUCTS

Export Controls

The Department of Commerce administers all export controls on crude oil. It derives its authority for such control from five statutes: the Export Administration Act of 1979, as amended; section 103 of the Energy Policy and Conservation Act of 1975; section 201(11) of the Naval Pe-

troleum Reserves Production Act of 1976 (10 U.S.C. 7430(3)); section 28 of the Mineral Leasing Act of 1920, as amended (50 U.S.C. 2406(d)); and the Outer Continental Shelf Lands Act of 1953 (43 U.S.C. 1354(d)). The export of any crude oil, including oil stored in the Strategic Petroleum Reserve (regardless of origin), is subject to export licensing pursuant to the Commerce Department's implementing regulations.

Crude Oil

In 1988, Canada and the United States signed the United States-Canada Free Trade Agreement, which removed virtually all barriers to trade between the two countries. This agreement, which became effective January 1, 1989, marked the culmination of efforts begun in March 1985, when President Reagan and Prime Minister Mulroney agreed that energy trade between the United States and Canada should be liberalized. They specifically recognized that restrictions on petroleum trade should be reduced. On June 1, 1985, as part of an effort to deregulate oil, Canada removed its remaining controls on oil exports. On June 14, 1985, President Reagan made the findings and determinations required by applicable export control statutes to allow U.S. crude oil (other than crude oil from the North Slope of Alaska or the Naval Petroleum Reserves) to be exported to Canada. Table A-1 shows how much crude oil the United States exported to Canada each year between 1986 and 1993. Under the Free Trade Agreement, the United States agreed to allow the export of up to 50,000 barrels (6,850 metric tons) per day (on an annual average basis) of crude oil from the North Slope of Alaska to

Table A-1—U.S. crude oil exports to Canada

Year	Exports, in barrels (metric tons)	
1986	6,040,000	(827,480)
1987	5,988,000	(820,356)
1988	3,737,000	(511,969)
1989	2,739,000	(375,243)
1990	3,974,000	(544,438)
1991	1,937,000	(265,369)
1992	1,065,000	(145,905)
1993	738,000	(70,996)

Source: U.S. Department of Energy, Energy Information Administration, *Petroleum Supply Annual 1992* (Washington, D.C.: U.S. Department of Energy, May 1993) and *Petroleum Supply Monthly* (Washington, D.C.: U.S. Department of Energy, February 1994).

Canada; any ocean transportation of such oil must be by vessels documented under U.S. law.

Refined Petroleum Products

Table A-2 summarizes daily exports to Canada of refined petroleum products from the United States and its territories from 1986 through 1993.

NATURAL GAS

Export Controls

The Secretary is responsible for developing U.S. policy governing natural gas exports. Section 301(b) of the Department of Energy Organization Act in effect vests in the Secretary the legal authority to regulate both the export and the import of natural gas. The Secretary delegated aspects of this authority to the Administrator of the Economic Regulatory Administration and to the Federal Energy Regulatory Commission.

Table A-2—U.S. exports to Canada of refined petroleum products

Year	Daily exports, in barrels (metric tons)	
1986	69,000	(9,500)
1987	66,000	(9,000)
1988	73,000	(10,000)
1989	85,000	(11,600)
1990	80,000	(11,000)
1991	65,000	(8,900)
1992	61,000	(8,400)
1993	70,000	(9,600)

Source: U.S. Department of Energy, Energy Information Administration, Integrated Petroleum Supply Reporting System, EM-522, IPS Data Base, April 19, 1994, and *Petroleum Supply Monthly* (Washington, D.C.: U.S. Department of Energy, February 1994).

Delegation Order 0204-111 requires the Assistant Secretary of Fossil Energy to determine whether the proposed export of natural gas is consistent with the public interest pursuant to section 3 of the Natural Gas Act. This determination is based on the domestic need for the natural gas in question and on any other matters pertinent to a particular export that the administrator considers appropriate.

Under Delegation Order 0204-112, the Federal Energy Regulatory Commission has the authority to approve or reject applications for the siting, construction, and operation of particular natural gas facilities involved in exports.

Industry Trends

All companies exporting natural gas are primarily U.S. owned. With the exception of the Phillips Petroleum Company and the Marathon Oil Company, the companies exporting natural gas are gas transmission or distribution companies with limited energy resource production capacity. Table A-3 summarizes U.S. exports of natural gas from 1986 through 1993.

Table A-3—U.S. natural gas exports

Year	Annual exports in billions of cubic feet (billions of cubic meters)
1986	61 (2)
1987	54 (2)
1988	74 (2)
1989	107 (3)
1990	86 (2)
1991	129 (4)
1992	216 (6)
1993	142 (4)

Source: U.S. Department of Energy, Energy Information Administration, *Monthly Energy Review* (Washington, D.C.: U.S. Department of Energy, March 1994).

Table A-4—U.S. coal exports

Year	Annual exports in millions of short tons (millions of metric tons)
1986	85.5 (77.6)
1987	79.6 (72.2)
1988	95.0 (86.2)
1989	100.8 (91.4)
1990	105.8 (96.0)
1991	109.0 (99.0)
1992	102.5 (93.0)
1993	74.5 (67.6)

Source: U.S. Department of Energy, Energy Information Administration, *Monthly Energy Review* (Washington, D.C.: U.S. Department of Energy, March 1994).

COAL

Export Controls

The Department was not able to identify coal exports by producing company or mine because independent coal brokers generally control transactions. Statistical reporting information currently available does not permit identification of coal brokers or coal exports of record by national origin. However, it appears that most exporters of U.S. coal are U.S.-owned coal and energy corporations. DOE does not administer any regulations concerning the export of coal; that is a function handled by the Department of Commerce.

Industry Trends

Table A-4 shows how much coal the United States exported each year between 1986 and 1993.

The United States continued to be the world's second-largest exporter of coal in 1992. Half of its exports went to Western Europe, with Italy being the leading importer

of U.S. coal in the region (9 million short tons or 8 million metric tons). Canada was still the biggest importer of U.S. coal worldwide (15 million short tons or 14 million metric tons) (U.S. Department of Energy, Energy Information Administration, *Annual Energy Review 1993* (Washington, D.C.: Government Printing Office), and *Quarterly Coal Report* (Washington, D.C.: Government Printing Office, DOE/EIA-0121 (92/4Q))).

The export outlooks for before and after the turn of the century are different. Yearly exports should rise moderately through the year 2000, to 144 million short tons (131 million metric tons), with most of the increase over 1990 levels occurring after 1995. The moderation of this rise reflects competition from Colombia, Venezuela, China, and Indonesia, which are developing their coal reserves for export. After 2000, U.S. exports should rise sharply, to 235 million short tons (213 million metric tons) in 2010. This projection of a sharp rise is based on three major factors: declining coal production in Europe as trade barriers fall, limited availability of Russian natural gas for export, and limited capability of other coal-exporting countries to increase their shipments after 2000 (U.S. Department of Energy, Energy Information Administration, *Annual Energy Outlook 1994* (Washington, D.C.: Government Printing Office)).

URANIUM

Export Controls

The export of uranium from domestic sources is controlled under the Atomic Energy Act of 1954, as amended, and under the Nuclear Non-Proliferation Act of 1978. The Nuclear Regulatory Commission issues licenses for uranium exports that comply with the provisions of section 127 of the Atomic Energy Act and any other applicable statutory requirements. The exporters must be able to guarantee that only authorized parties will be able to use the material, that no one will use the material for research on or development of any nuclear explosive device, and that they will maintain adequate physical security.

Industry Trends

Table A-5 lists exports of uranium yellow cake (U_3O_8) to Far Eastern and Western European markets from 1986 to 1993.

Table A-5—U.S. exports of uranium yellow cake

Year	Annual exports in millions of pounds (millions of kilograms)	
1986	1.6	(0.7)
1987	1.0	(0.5)
1988	3.3	(1.5)
1989	2.1	(1.0)
1990	2.0	(0.9)
1991	3.5	(1.6)
1992	3.0	(1.4)
1993	2.8 ^a	(1.3)

Source: U.S. Department of Energy, Energy Information Administration, *Uranium Industry Annual 1993* (Washington, D.C.: U.S. Department of Energy, October 1993).

^aPreliminary

APPENDIX B

DISCLOSURE OF ENERGY ASSETS BY DOE EMPLOYEES

INTRODUCTION

The National Defense Authorization Act for Fiscal Year 1994 (Public Law No. 103-160) repealed sections 603 through 607 of the Department of Energy Organization Act (Public Law No. 95-91; the organization act), effective November 30, 1993. Prior to the repeal of these sections of the organization act, section 603(a) required Department employees to disclose energy assets within 30 days after commencing service with the Department and annually on May 15 thereafter. Section 603(b)(2) required that a report with respect to such disclosures and the actions taken in regard thereto during the preceding calendar year be included in DOE's *Annual Report to Congress*. Accordingly, this appendix covers actions taken pursuant to section 603 in calendar year 1992 and calendar year 1993 through November 30, 1993, as well as certain activities during that period and in December 1993 pertaining to other sections of title VI of the organization act.

SECTION 603

In 1992 and 1993, the Department required that employees submit annual reports for the previous calendar year to fulfill the requirements of section 603(a) of the organization act, title I of the Ethics in Government Act of 1978 (Public Law No. 95-521, as amended by Public Law No. 101-194 and Public Law No. 101-280) and Executive Order 12674 (as modified by Executive Order 12731). All employees of the Department were required to file finan-

cial disclosure reports, except those holding positions at or below grade GS-12 that were determined to be nonregulatory and nonpolicymaking. Employees subject to the public financial disclosure requirements of the Ethics in Government Act were requested to file Standard Form 278, "Public Financial Disclosure Report;" other employees were asked to file Form DOE 3735.1, "Report of Financial Interests," as required by section 603(a) of the organization act, which was repealed effective November 30, 1993. In addition to the annual submissions, these reports were required from Department employees when they began and terminated service.

OTHER SECTIONS OF THE ACT

Section 602(a) of the organization act prohibits supervisory employees (as defined in section 601(a) of the organization act) from knowingly receiving any compensation from, holding any official relation with, owning stocks or bonds of, or having any other pecuniary interest in any energy concern. This provision was not repealed. As a result of the review of financial disclosure reports submitted by supervisory employees, 35 employees were directed to divest of energy concern interests in calendar years 1992 and 1993.

Section 602(c) of the organization act provides that where exceptional hardship would result or where the interest is a pension, insurance, or other similarly vested interest, the Secretary may waive the divestiture requirements of section 602(a) for such period as the Secretary may prescribe. Such waivers must be published in the Federal Register. The Secretary granted waivers pursuant

to this authority to 11 persons in calendar years 1992 and 1993.

Section 604 of the organization act required each new supervisory employee to file a report identifying any energy concern that paid the employee compensation in excess of \$2,500 in any of the previous five calendar years. Upon assuming a supervisory employee position, an employee was required to submit this report (Form DOE 460/2000.2, "Report on Prior Employment"). This provision was repealed effective November 30, 1993.

Section 605(a) of the organization act restricted appearances before or communications with the Department by former supervisory employees for one year after leaving the Department. Until November 30, 1993, the date this provision was repealed, the Department regularly provided advice to departing employees regarding this restriction, as well as the requirement in section 605(b) that former supervisory employees file reports of employment with energy concerns (Form DOE 461/2000.3, "Report of Employment—Former Supervisory Employees"). Such reports were due on May 15 of the first and second calendar years following the termination of a Department employment.

Section 605(a) of the organization act authorized waiver of this post-employment restriction, where the national interest would be served, to permit a former supervisory employee with outstanding scientific or technological qualifications to appear before or communicate with the Department in connection with a particular matter in a scientific or technological field. Such waivers were required to be published in the *Federal Register*. This provision was repealed effective November 30, 1993. During

calendar year 1992 and calendar year 1993 through November 30, 1993, no waivers of the post-employment restriction of section 605(a) were granted.

During a supervisory employee's first year with the Department, section 606 of the organization act limited his or her participation in DOE proceedings involving former employers that are energy concerns. This provision was repealed effective November 30, 1993. The Secretary was authorized to waive these limitations where their application would be an exceptional hardship for the employee or contrary to the national interest. During calendar year 1992 and calendar year 1993 through November 30, 1993, one waiver of section 606 restrictions was granted with respect to a supervisory employee who began service in the Department in calendar year 1991.

Section 607(a) of the organization act required that reports submitted under section 603, 604, or 605 be available to the public. In addition, with certain exceptions, reports filed under title I of the Ethics in Government Act of 1978 are available to the public pursuant to section 105 of that title. An employee whose report is released to a member of the public is promptly notified of the release and the identity of the requester. During calendar years 1992 and 1993, copies of 54 reports submitted under the Ethics in Government Act of 1978 were provided to requesters.

Section 608 of the organization act establishes civil and criminal penalties for violation of the reporting and other requirements of title VI. The Department took no action pursuant to this authority during calendar years 1992 and 1993.

APPENDIX C

OFFICE OF HEARINGS AND APPEALS

INTRODUCTION

The Office of Hearings and Appeals is the focus of DOE's adjudicatory and appellate activities. The office carries out a broad range of activities related to DOE programs and regulations, and it analyzes and decides applications for exception from DOE regulatory requirements. In addition, orders of the Department (other than those issued by the Federal Energy Regulatory Commission) generally are appealable to the Office of Hearings and Appeals. The office adjudicates enforcement cases involving prior DOE price and allocation regulations and decides disputes concerning payments-equal-to-taxes determinations made in connection with DOE high-level radioactive waste and spent nuclear fuel repository sites.

During the period October 1, 1991, through September 30, 1993, the office continued processing petitions and applications to refund more than \$112 million deposited with DOE as a settlement of various petroleum overcharge compliance proceedings. In addition to written decisions on approximately 21,000 refund applications and related matters, the Office of Hearings and Appeals issued more than 300 other determinations, many of which are subject to appeal to either a Federal court or the Federal Energy Regulatory Commission.

DETERMINATIONS MADE UNDER THE FEDERAL ENERGY ADMINISTRATION ACT OF 1974 (PUBLIC LAW 93-275, SECTIONS 21)

Between October 1, 1991, and September 30, 1993, the Office of Hearings and Appeals received three new petitions for special redress (as shown in Table C-1) and resolved three petitions for Special Redress as follows.

ARKANSAS (5/29/92)(LEG-0004)

DOE issued a decision and order denying a petition for special redress filed by the State of Arkansas, which sought approval of a proposed Reactive Fuel Additive Research Program that would use oil overcharge funds to underwrite research to develop a substance to reduce the volatility of stored motor fuel. The Decision upheld two earlier determinations by the Office of Financial and Technical Assistance denying the request and finding that use of oil

**Table C-1—Petitions for special redress received
by the Office of Hearings and Appeals
October 1, 1991, through September 30, 1993**

Petitioner	Case Number
State of Arkansas	LEG-0004
State of California	LEG-0005
State of Texas	LEG-0003

overcharge funds by the program would be inconsistent with the restitutionary goals of the Stripper Well Settlement Agreement.

CALIFORNIA (7/27/93) (LEG-0005)

DOE issued a decision and order denying a petition for special redress filed by the State of California. In its petition, California requested that it be permitted to use \$300,000 in Stripper Well funds for the construction of a

child care center near a commuter rail station, a program which had twice been rejected by the Deputy Assistant Secretary, Energy Efficiency and Renewable Energy, as inconsistent with the terms of the Stripper Well Settlement Agreement. The Office of Hearings and Appeals found that the State had failed to demonstrate that the child care proposal either (a) fell within the categories of programs explicitly permitted by the Settlement Agreement or (b) adhered to the equitable guidelines outlined for new or unique programs. Consequently, California's petition for special redress was denied.

TEXAS (5/28/92)(LEG-0003)

DOE issued a decision and order denying a petition for special redress filed by the State of Texas which sought approval of a proposed Reservoir Conservation Program that would use oil overcharge funds to subsidize the plugging of abandoned oil wells on State lands. The decision upheld an earlier determination by the Office of Financial and Technical Assistance denying the program as being inconsistent with the restitutionary goals of the Stripper Well Settlement Agreement.

APPENDIX D

INTERAGENCY GEOTHERMAL COORDINATING COUNCIL

1992 ANNUAL REPORT

SUBMITTAL STATEMENT

Congress established the Interagency Geothermal Coordinating Council under Public Law 93-410, the Geothermal Energy Research, Development, and Demonstration Act of 1974 (as amended by Public Laws 95-238 and 95-91), to coordinate Federal plans, activities, and policies that relate to or affect geothermal energy. In accordance with section 202 of Public Law 93-410, the council, on behalf of the Secretary of Energy, has prepared an annual report of Federal activities and programs in geothermal energy. As chairman of the council, and in compliance with the act, I am pleased to present the Seventeenth Annual Report to Congress.

Frank M. Stewart, Jr.
Acting Assistant Secretary
Energy Efficiency and Renewable Energy

INTRODUCTION

Congress established the Interagency Geothermal Coordinating Council in 1974 under Public Law 93-410, the Geothermal Energy Research, Development, and Demonstration Act of 1974 (as amended). The council's objective is to coordinate a national geothermal energy research, development, and demonstration program and to serve as a forum for discussion of Federal plans, activi-

ties, and policies that relate to or affect geothermal energy. The council is composed of assistant secretaries from the Departments of Energy, the Interior, the Treasury, Agriculture, Defense, Commerce, and Housing and Urban Development and an assistant administrator from the Environmental Protection Agency. An assistant secretary from DOE, in 1992 the then-Acting Assistant Secretary for Energy Efficiency and Renewable Energy, chaired the council. The provisions of Public Law 93-410 require the council to prepare and submit to the President and Congress an annual report on Federal activities and programs in geothermal energy. In response to that mandate, this report describes the Federal geothermal energy programs and their status and accomplishments in 1992.

Based on Energy Information Administration data (Form EIA-860, "Annual Electric Generator Report," and Form EIA-867, "Annual Nonutility Power Producer Report") geothermal energy supplies about 0.5 percent of the Nation's electricity. In 1992, geothermal generating units in the United States produced more than 16 million megawatthours (58 petajoules) of electricity.

Energy Information Administration data also show that more than 90 percent of the nonutility power producers that use geothermal energy are certified as qualifying facilities by the Federal Energy Regulatory Commission (FERC). Approximately 201 geothermal generating units were operating at the end of 1992, with a total installed nameplate capacity of 3,119 megawatts. Nonutility power producers represented 1,250 megawatts, or 40 percent of geothermal capacity, and operated 172 generating units; electric utilities owned 1,869 megawatts, or 60 percent of geothermal capacity, and operated 29 generating units. Most of the geothermal capacity operated by electric utilities is located at The Geysers in California.

As of the end of 1991, electric utilities planned to construct no new geothermal generating units between 1992 and 2001. Nonutility power producers, however, planned additions of approximately 313 megawatts through 1995.

CERTIFICATION

Commercial production of electric power from geothermal resources in the United States began in 1960. In 1980, certification of qualifying status for nonutility small power and cogeneration facilities (including geothermal facilities) was begun by FERC (see the *Code of Federal Regulations*, title 18, section 292). The Solar, Wind, Waste, and Geothermal Power Production Incentives Act of 1990 (Incentives Act), Public Law 101-575, as amended by Public Law 102-46, removed the size limitation of 80 megawatts for qualifying facilities whose primary energy sources were solar, wind, waste, or geothermal, if they met certain conditions.

From March 1980, when the qualification of small power production and cogeneration facilities began, through the end of 1992, FERC certified or received notices of self-certification for approximately 3,087 megawatts of qualifying geothermal electric power generating capacity. During 1992, seven prospective geothermal small power production facilities, with a proposed combined capacity of 188.7 megawatts, filed applications for certification or notices of self-certification with FERC. In addition, three geothermal small power production facilities revised their capacities for a proposed net increase of approximately 10 megawatts.

LEASING

At the end of calendar year 1992, 186 competitive and 349 noncompetitive leases were in effect under the Federal Geothermal Leasing Program conducted by the U.S. Bureau of Land Management, which makes Federal lands available to industry for environmentally acceptable exploration and development. Geothermal electric powerplants sited on these Federal leases—located primarily in the West and Southwest—had a combined capacity of 1,146 megawatts in calendar year 1992 (this total includes some capacity from powerplants sited on private lands that used Federal geothermal resources). The collection of royalty, rent, and bonus revenues during 1992 totaled some \$17 million; the Federal Government shared

this income with the states within whose boundaries the Federal leases are located.

An interagency agreement was developed among the U.S. Forest Service, the Bonneville Power Administration, and the U.S. Bureau of Land Management to work with a private contractor to prepare an environmental impact statement addressing exploration and development for a 30-megawatt powerplant within the Deschutes National Forest in central Oregon. Funding for the environmental impact statement is to be provided by the developer. The contractor was selected, and scoping for the environmental impact statement was initiated.

RESEARCH

Since 1971, DOE and its predecessor agencies have sponsored research and development on geothermal energy to establish a technology base that enables private enterprise to develop geothermal resources in direct-heat and electric-power energy markets. In recent years, the Department's Geothermal Division has focused its activities on satisfying immediate industry needs that promise the greatest payoff to industry in the near to midterm. With industry directly participating in cost-shared research and development, both the Federal Government and industry are leveraging their limited resources to develop and commercialize new geothermal technology.

During 1992, The Geysers geothermal field, the largest in the United States, continued to undergo a decline in reservoir pressure as a consequence of several decades of removal of fluid from the geologic formation without adequate replenishment. National laboratory analyses of historical data of the field provided insight into where fluid injection would be most effective at replenishing the reservoir, based on reservoir pressure, structure, geometry, and permeability. Injection tests to date have yielded promising results. Researchers also developed the first detailed evolutionary geochemical model of The Geysers geothermal system.

Researchers completed electromagnetic field surveys over several hidden and exposed geothermal systems in cooperation with industry and state resource teams in Nevada, New Mexico, and Utah. Geothermal reservoir engineers developed a preliminary model of the Coso, California, geothermal system from a detailed evaluation of fluid inclusion data, new modeling of the early fluids discharged from the wells, and newly developed thermal data. They identified prospective sites for drillers to access the geothermal resource with slim-hole drilling tech-

nology and to compare reservoir parameters measured in these slim holes with data from conventional production-size wells. In 1992, researchers also combined computer programs that calculate geothermal well bore and reservoir conditions and applied the resultant program to derive geothermal reservoir parameters from slim-hole flow data. These developments will help validate use of slim-hole drilling for geothermal exploration and confirmation at substantially reduced costs in comparison with drilling production-size wells.

Materials scientists began work on improving the fabrication of corrosion- and scale-resistant liners for heat exchanger tubing. They developed a lightweight, carbon dioxide-resistant cement for geothermal wells, which is being transferred to industry. Industry also welcomed a DOE-sponsored computer model that predicts where and under what conditions scale will form in a geothermal plant. Empirical analysis of fluid flow in geothermal reservoirs will benefit from two new fluorescent tracers that enhance tracking the underground flow of fluids in geothermal reservoirs at temperatures up to 220 degrees Celsius.

Drilling researchers developed the rolling float meter, a new instrument that will ameliorate "lost circulation," a problem that occurs when expensive drilling fluids flow unexpectedly into highly permeable rock formations or fractures. The instrument measures the rate at which circulating drilling fluids are leaving a well. Industry is testing several rolling float meter units at geothermal sites, and it has conducted successful field tests with a jointly developed borehole televiewer that measures properties of fractures that intersect boreholes. Drilling researchers also made significant advances in the development of a new telemetry system for communicating data up and down a well during drilling operations.

Geologists began an assessment of low-temperature geothermal resources and began an inventory of resources collocated with markets for their energy. A geothermal engineering group published and distributed a revised edition of the *Geothermal Direct Use Engineering and Design Guidebook*, which will assist individuals, businesses, and communities in using the Nation's abundant low- to moderate-temperature geothermal resources.

In conducting advanced geothermal technology activities, hot dry rock researchers focused on testing of the surface facility at Fenton Hill, New Mexico, in preparation for a long-term flow test. Researchers completed a number of short-term flow tests to establish operating parameters for the continuous test phase. They conducted the tests under conditions designed to maintain reservoir stability and to obtain useful operational data. Tracer results indicated that a significant fraction of water injected

during flow tests goes into reservoir flow paths contributing to the heat extraction process. The total volume of all flow paths transmitting fluid from the injection to the production wells increased. This increase could have resulted from thermal contraction of the rock in the region of the outlets to the reservoir from the injection wellbore, but additional flow paths connecting the wellbores also may have contributed to the increased fluid volume. Logging results indicated an increase in fluid access to more remote portions of the reservoir, enhancing its thermal performance. In the culmination of geopressured technology activities, researchers concluded a long-term flow test of the Pleasant Bayou well in a Texas geopressured geothermal reservoir and prepared to initiate plugging operations.

The U.S. Geological Survey completed a number of studies in 1992 to characterize geothermal fields. The survey published a series of technical papers that will help in delineating the evolution of the geothermal system of the Lassen volcanic center in California, and it provided technical assistance to a number of countries on studies of geothermal field resource characterization and development. Chemical and geophysical studies of reservoir conditions of The Geysers in northern California were continued in collaboration with DOE and private industry, in an attempt to understand causes of declining production pressures and to prolong the reservoir's production lifetime. U.S. Geological Survey scientists also played a major role in organizing and contributing to the technical content of the Seventh International Symposium on Water-Rock Interaction held in Park City, Utah, from July 13 to July 22, 1992.

ENVIRONMENTAL COMPLIANCE

The Environmental Protection Agency's principal role in geothermal development is to assess environmental parameters and to help responsible parties control significant pollution problems. The agency, which has not targeted funds specifically for geothermal energy compliance, provides guidance, standards, and pollution control regulations. No specific geothermal regulations are in force, but installations must meet Environmental Protection Agency (or state, where delegated) permitting requirements for acceptable discharge levels of pollutants into the atmosphere, in and to receiving waters, in drinking-water aquifers, and on land.

In 1992, the Environmental Protection Agency continued to monitor the progress of geothermal developers. As

of the end of the year, the agency had planned no regulatory actions that would affect the geothermal industry alone.

DEVELOPMENT AND EXPLORATION

The Department of Commerce continued to assist U.S. industry in developing market and project opportunities around the world. The International Trade Administration, following the issuance of a certificate of review, continued to work with the industry's export trading company, the U.S. Geothermal International Corporation, to identify and pursue private power opportunities for geothermal energy in a number of developing countries. The Market Development Assistance Subcommittee of the interagency Committee on Renewable Energy Commerce and Trade (CORECT), as part of its Pacific Rim and Pacific Islands Project Identification Efforts, sponsored international conferences in Los Angeles in 1991 and in Hawaii in 1992. Among the end-use applications featured at these trade events were modular, utility-scale geothermal power stations. The International Trade Administration's Office of Energy, Environment and Infrastructure supported efforts by the U.S. Geothermal International Corporation and the industry's National Geothermal Association to bring Pacific Rim and Pacific Island utility and government energy officials to these conferences and to participate in geothermal site visits in California and Hawaii. The Office of Energy, Environment and Infrastructure also continued to monitor progress in geothermal power development in the United States. International Trade Administration's International Major Projects Division assisted U.S. geothermal companies in competing for multilateral-development-bank-funded projects in key foreign countries.

The Department of the Navy, which uses geothermal energy for district heating at Keflavik, Iceland, and for electric power generation at the China Lake Naval Air Weapons Center in California, increased its program funding level for 1992 by 40 percent and was scheduled to maintain that level for 1993. The Navy's goal remains to develop three additional geothermal production contracts by the end of the century. Three sites within California are still being assessed.

To date, exploratory drilling at the Marine Corps' Air-to-Ground Combat Center at Twenty Nine Palms, California, has not located a viable geothermal resource. The

first phase of exploratory drilling at the Mainside location at China Lake Naval Air Weapons Center remains encouraging, and if a resource is proven, it will be the second reservoir at the China Lake Naval Air Weapons Center. The data indicate a high probability of a geothermal resource having an excellent potential for district heating and a probable potential for electric power generation. The Department of the Navy, designated by the Deputy Assistant Secretary of Defense for Logistics as the lead geothermal development agency for the Department of Defense, is assisting the U.S. Army in its exploration efforts at Fort Irvin, California.

The Navy project at its Coso, California, site remains in full production, with 160 megawatts from two plants on Navy land and 80 megawatts from two plants on land administered by the Bureau of Land Management. Efforts to develop a potential geothermal resource at the Naval Air Station at Fallon, Nevada, have continued under a public-private venture contract; the Navy will drill discovery wells in 1993 and then solicit a contract in 1994.

INCENTIVES

Financial and economic incentives for private-sector development of geothermal resources are provided by other Federal agencies. The Department of Housing and Urban Development offers financing opportunities for geothermal development through its Community Development Block Grant programs.

DOE used its geothermal loan guaranty authority established by the Geothermal Energy Research, Development, and Demonstration Act of 1974 to assist in the financing of various geothermal projects. The guaranty program has largely fulfilled its purpose, with eight guaranties or commitments issued since its inception. Of these, four loans have been repaid and their guaranties have been released (\$106.7 million face amount, \$99.4 million actually disbursed); recipients of the remaining four loans (\$184.6 million face amount, \$38.7 million actually disbursed) have defaulted, and the loans have been paid off by DOE under its guaranty obligations. In some instances, the Federal Financing Bank of the Department of the Treasury has acted as the lender under DOE loan guaranties. In 1992, no new loans were financed by the Federal Financing Bank under DOE's geothermal loan guaranty authority.

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1993 ANNUAL REPORT

SUBMITTAL STATEMENT

Congress established the Interagency Geothermal Coordinating Council under Public Law 93-410, the Geothermal Energy Research, Development, and Demonstration Act of 1974 (as amended by Public Laws 95-238 and 95-91), to coordinate Federal plans, activities, and policies that relate to or affect geothermal energy. In accordance with section 202 of Public Law 93-410, the council, on behalf of the Secretary of Energy, has prepared an annual report of Federal activities and programs in geothermal energy. As chairman of the council, and in compliance with the act, I am pleased to present the Eighteenth Annual Report to Congress.

Christine A. Ervin
Assistant Secretary
Energy Efficiency and Renewable Energy

INTRODUCTION

The Interagency Geothermal Energy Coordinating Council was established by Congress in 1974 under Public Law 93-410, the Geothermal Energy Research, Development, and Demonstration Act of 1974 (as amended). The council's objectives are to coordinate a national geothermal energy research, development, and demonstration program and to serve as a forum for discussion of Federal plans, activities, and policies that relate to or affect geothermal energy. The council is composed of assistant secretaries from the Departments of Energy, Interior, Treasury, Agriculture, Defense, Commerce, and Housing and Urban Development and an assistant administrator from the Environmental Protection Agency. An assistant secretary from the Department of Energy, the Assistant Secretary

for Energy Efficiency and Renewable Energy, chairs the council. The act requires the council to prepare and submit to the President and Congress an annual report on Federal activities and programs in geothermal energy. In response to that mandate, this report describes the Federal geothermal energy programs and their status and accomplishments in 1993.

In 1993, geothermal generating units in the United States produced more than 16 million megawatthours (58 petajoules), supplying 0.5 percent of the Nation's electricity, based on Energy Information Administration data from Form EIA-860, "Annual Electric Generator Report"; Form EIA-759, "Monthly Power Plant Report"; and Form EIA-867, "Annual Nonutility Power Producer Report."

Based on the latest available Energy Information Administration data in 1993, 201 geothermal generating units were operating, with a total installed nameplate capacity of 3,123 megawatts. Nonutility power producers represented 1,254 megawatts, or 40 percent of geothermal capacity, and operated 172 generating units. Electric utilities owned 1,869 megawatts, or 60 percent of geothermal capacity, and operated 29 generating units. Most of the geothermal capacity operated by electric utilities is located at The Geysers in California. More than 90 percent of the nonutility power producers that use geothermal energy are certified as qualifying facilities by the Federal Energy Regulatory Commission.

According to Energy Information Administration surveys (Form EIA-860), electric utilities have no plans to construct new geothermal generating units between now and the year 2001. Nonutility power producers, however, plan to add 313 megawatts by 1995.

CERTIFICATION

The Federal Energy Regulatory Commission (see the *Code of Federal Regulations*, title 18, section 292) started certification of qualifying status for nonutility small power and cogeneration facilities (including geothermal facilities) in 1980. Under the Public Utilities Regulatory Policies Act of 1978, the size limitation for geothermal qualifying facilities was 80 megawatts. This size limitation was temporarily removed by the Solar, Wind, Waste, and Geothermal Power Production Incentives Act of 1990 (Public Law 101-575), as amended by Public Law 102-46.

The Federal Energy Regulatory Commission certified or received notices of self-certification for 3,187.7 megawatts of qualifying geothermal electric-power-generating capacity from March 1980 through the end of 1993 (not

all certified facilities were necessarily operating at this time). During 1993, the Federal Energy Regulatory Commission received applications for certification or notices of self-certification from three prospective geothermal small power producers, with a proposed combined capacity of 92 megawatts. Two other geothermal small-power-production facilities revised their capacities, for a proposed net increase of 8.3 megawatts.

LEASING

The Federal Geothermal Leasing Program had 190 competitive and 355 noncompetitive leases as of the end of 1993. This program makes Federal lands available to industry for environmentally acceptable exploration and development. Federal leased lands for geothermal electric power plants are primarily located in the West and Southwest. In 1993, there was a combined geothermal electric-power capacity of 1,146 megawatts in geothermal plants sited on Federal leased land (including some capacity from powerplants sited on private lands that used Federal geothermal resources). The Federal Government collected approximately \$17 million during 1993 from royalty, rent, and bonus revenues. Some of this income was shared with the states within whose boundaries the Federal leases are located.

RESEARCH

Since 1971, the Department of Energy and its predecessor agencies have sponsored research and development on geothermal energy to establish a technology base that enables private enterprise to develop geothermal resources at competitive cost in electric-power and direct-heat energy markets. In recent years, the Department's Geothermal Division has focused its activities on satisfying immediate industry needs that promise the greatest payoff to industry in the near- to mid-term. With industry directly participating in cost-shared research and development, both the Federal Government and industry are leveraging their limited resources to develop and commercialize new geothermal technology.

Recent analyses of geothermal development costs identify exploration and reservoir assessment drilling costs to be as much as 35 to 50 percent of total project cost. Slim-hole drilling has been shown to reduce oil and gas exploration costs by 25 to 75 percent; however, geothermal

resources present unique challenges that require further investigation before similar conclusions for geothermal applications can be confirmed. The Department has initiated research to demonstrate that a geothermal reservoir can be reliably assessed with data collected from slim holes.

Stabilization of the reservoir pressure decline at The Geysers geothermal field in California continues to command the interest of the geothermal industry. The decline has resulted from several decades of production without sufficient replenishment of the fluids removed. Several research efforts are focused on maximizing extraction of the substantial amount of heat remaining in the reservoir rocks at The Geysers. In 1993, joint industry-government research demonstrated the effectiveness of injecting water to recharge the geothermal reservoir and to rebuild steam pressures that have diminished over 30 years of production. A consortium of local, state, Federal, and industry interests completed engineering and environmental studies for a proposed pipeline to transport effluent from nearby communities to The Geysers for use as recharge water. Current studies of the physical properties of reservoir rocks at The Geysers will provide seismologists with a new technique to distinguish between productive and unproductive parts of the reservoir.

The rapidly growing computational capability of personal computers now allows industry to perform complex geothermal modeling at the work site. Such geothermal modeling programs are being translated for use on personal computers, so that even small geothermal companies will have the capability to optimize reservoir production strategies.

In 1993, the Department of Energy and a group of drilling manufacturers began a cost-shared research and development program to develop new synthetic-diamond drill bits for hard-rock drilling. Drilling researchers continued efforts to develop a suite of instruments capable of withstanding harsh, high-temperature conditions to provide downhole data important to the development and maintenance of a geothermal field. These efforts included completion of design and fabrication of three precision pressure-temperature tools and two field logging applications for the borehole televiewer.

DOE researchers began a series of experiments in 1993 at the Heat Cycle Research Facility in California's Imperial Valley to confirm the performance benefits of supersaturated turbine expansions. Supersaturated turbine expansions are expected to provide an 8-percent increase in electric-power output from binary cycle geothermal plants, corresponding to a 4- to 8-percent reduction in the cost of producing power. The Department also initiated a cost-shared program with two energy companies to dem-

onstrate the economic benefits of improved electric generators for geothermal applications.

At a geothermal plant in California's Imperial Valley, materials scientists began a 100-day field test of heat exchanger tubes with thermally conductive polymer concrete linings developed to inhibit corrosion and scaling. If successful, this technology will substantially reduce the capital cost of geothermal binary cycle plants. Preliminary results indicate the thermal and hydraulic performance of the thermally conductive polymer linings are comparable to that of high-alloy steels. The Magma Power Company participates in this field test and shares its cost with the Department of Energy.

To promote the benefits of geothermal heat-pumps, the Department organized and aired two national teleconferences in 1993. The teleconferences were organized for utility audiences, HVAC/building contractors, architects, and engineers. The Department of Defense's Strategic Environmental Research and Development Program provided \$1.8 million to design, introduce, and monitor geothermal heat-pump installations at various Department of Defense sites.

The Department of Energy is funding a new project at the Southwest Technology Development Institute to build a geothermally heated aquaculture facility that will use geothermal fluid cascaded from a greenhouse to raise tilapia, a tropical fish. This project will further demonstrate the economic benefits of cascaded geothermal direct-use applications.

During 1993, as part of the hot dry rock commercialization effort, the Department of Energy continued industrial cooperation and technology transfer activities, including the signing of the first formal memorandum of understanding with a private organization to work together toward implementing hot dry rock technology. An important result of this effort is the first-ever offer by a private geothermal company to extract energy from hot dry rock resources in response to a power company request for proposals to supply electricity for commercial distribution.

Researchers completed a limited long-term testing at the Fenton Hill hot dry rock facility. Results showed that operation of the facility under the standard closed-loop operating conditions produced no atmospheric emissions. Results of surface measurements and temperature logs at depth showed no decrease in the average temperature of the fluid produced from the reservoir over the span of the long-term testing effort. Further, results from multiple tracer tests showed that additional hot rock within the reservoir was continually accessed and that the volume of the water stored in the reservoir increased as flow testing proceeded.

Since the early 1970s, the U.S. Geological Survey (USGS), through its Geothermal Investigations Program, has studied the nature, distribution, and magnitude of U.S. geothermal resources as a basis for determining the appropriate long-term role of geothermal energy in the National Energy Policy.

As part of its geothermal program, the USGS characterizes the geoscientific nature of the various types of geothermal systems and quantitatively assesses the Nation's geothermal resources. It also investigates geoenvironmental changes that may result from the production or injection of geothermal fluids and studies the physical and chemical processes that produce exploitable geothermal resources.

The USGS geothermal program, interacting with the Survey's Volcano Hazards program, is currently completing a multiyear resource assessment of the Cascade volcanic arc in the Pacific Northwest. It is also studying the geothermal system along the east rift zone of Kilauea volcano in Hawaii and beginning new studies on the geothermal potential of Bureau of Land Management lands in northwest Nevada and southeastern Oregon.

The USGS is also producing new geologic maps for the Medicine Lake and Lassen Park areas in California, the Newberry and Crater Lake areas in Oregon, and the island of Hawaii. As an ongoing effort, the USGS conducts geoscientific studies to determine the potential effects of geothermal development on naturally flowing hot-spring systems in National Parks. Further, it is currently conducting high-resolution geophysical studies of The Geysers geothermal area.

The USGS, in cooperation with the Department of Energy and the Electric Power Research Institute, held a workshop in January 1993 on the potential of hot dry rock geothermal energy in the Eastern United States. The workshop was conducted as directed by Congress in section 2502 of the Energy Policy Act of 1992 (Public Law 102-486). Results of this workshop are summarized in a separate report to Congress.

ENVIRONMENTAL COMPLIANCE

The Environmental Protection Agency provides guidance, standards, and pollution control regulations to help geothermal developers control significant pollution problems. The agency has no funds targeted specifically for geothermal energy compliance, and no specific geothermal regulations are in force; but installations must meet Environmental Protection Agency (or state, where delegated)

permitting requirements for acceptable atmospheric and surface discharge levels.

In 1993, the Environmental Protection Agency continued to monitor the progress of geothermal developers. As of the end of the year, the agency had planned no regulatory actions that would affect the geothermal industry alone.

The U.S. Forest Service, the Bonneville Power Administration, and the U.S. Bureau of Land Management are parties in an interagency agreement to work with a private contractor to prepare an environmental impact statement for a 30-megawatt powerplant within the Deschutes National Forest in central Oregon. Preparation of the draft environmental impact statement for the project is under way; funding will be provided by the geothermal developer.

DEVELOPMENT AND EXPLORATION

Unocal, a large producer of geothermal energy in the United States, successfully developed major geothermal energy fields in the Philippines in the 1970s. Patterned after their experience in The Geysers in northern California, Unocal extracted, transported, and sold vast quantities of geothermal steam in the Philippines to NAPOCOR, the country's utility, which enabled NAPOCOR to generate 660 megawatts of clean, renewable electric power.

Because of this early success and NAPOCOR's positive experience with geothermal energy, U.S. industry was well placed to develop additional utility-owned geothermal projects in Southeast Asia during the 1980s. However, stiff competition from foreign geothermal companies offering low-interest financing packages supported by their governments stymied U.S. industry market development efforts.

A joint Federal interagency-industry effort begun in 1988 provided key support to U.S. geothermal firms in identifying and developing geothermal private power projects. This effort has been coordinated by the Department of Commerce's International Trade Administration (ITA) and the Market Development Assistance Subcommittee of the Committee on Renewable Energy Commerce and Trade (CORECT). The Department of Energy, as chair agency of CORECT, ITA, and the industry's National Geothermal Association, worked with other CORECT member Federal agencies to coordinate U.S. government marketing assistance programs with U.S. company project development efforts, targeting Southeast Asia. A research

effort completed in 1990 identified promising project opportunities in the Philippines and Indonesia.

ITA's Pacific Basin country desk officers and Major Projects and Energy Division industry officers worked jointly with American embassy commercial officers to assist U.S. geothermal firms in pursuing private power opportunities. Following favorable review of the potential projects, the U.S. Export-Import Bank issued preliminary commitments of project financing. The U.S. Overseas Private Investment Corporation played an important role by offering investment insurance to individual geothermal firms for their proposed private power projects. The Department of Energy's Geothermal Division provided technical guidance to other U.S. agencies in assessing the resource and technology. The U.S. Agency for International Development offered key endorsements of these projects to senior Philippine and Indonesian government officials.

With this assistance, contractual commitments for a cumulative total of 650 megawatts of geothermal private power projects were signed in mid-1993 by the President of the Philippines and the chief executive officers of Magma Power Company, Mission Energy Corp., and Ormat, Inc. Additional geothermal private power project commitments have been signed by NAPOCOR and California Energy Company officials. Several months earlier, contractual commitments for as much as 1,000 megawatts of geothermal private power were signed by senior Indonesian officials and the Unocal Geothermal Corp.

Future CORECT interagency efforts will follow up this success by assisting U.S. industry with project development in the Pacific Rim, Central America, Eastern Europe, and the Newly Independent States (NIS) of the former Soviet Union. Further penetration of Federal assistance activity will facilitate this expanded scope of geothermal development, to allow participation by numerous smaller geothermal companies.

The Department of the Navy, designated by the Deputy Assistant Secretary of Defense for Logistics as the lead geothermal development agency for the Department of Defense, uses geothermal energy for district heating at Keflavik, Iceland, and for electric power generation at the China Lake Naval Air Weapons Station in California. The Navy increased its program funding for 1992 by 40 percent, maintained that level for 1993, and is scheduled to maintain that level for 1994. The Navy's goal remains to develop three additional geothermal production contracts by the end of the century. Three sites within California and one in Nevada are still being assessed.

To date, exploratory drilling at the Marine Corps' Air-to-Ground Combat Center at Twenty Nine Palms, California, has not located a viable geothermal resource. However, geophysical and geochemical data, obtained in part from the drilling, indicate that additional effort is warranted.

The first phase of exploratory drilling at the mainside location at China Lake Naval Air Weapons Center remains encouraging, based on the results of a 7,400-foot-deep test hole. If a resource is proven, it will be the second reservoir at China Lake. The data indicate a high probability of a geothermal resource with excellent potential for district heating and probable potential for electric power generation.

The Navy geothermal project at its Coso, California, site remains in full production, with a nameplate capacity of 170 megawatts from two plants on Navy land and 80 megawatts from two plants on land administered by the Bureau of Land Management. The Navy has drilled a 7,000-foot-deep confirmation hole at the Fallon Naval Air Station, located 60 miles east of Reno. Field data gathered over the last several years show the potential for a substantial resource beneath the mainside facilities at Fallon. This confirmation well produced commercial-grade geothermal fluids. The Navy and a resource development company are pursuing a public-private venture-capital contract agreement to construct and operate a power generation facility.

INCENTIVES

Financial and economic incentives for private sector development of geothermal resources are provided primarily via Federal tax policy, although some incentives are available from Federal agencies. In 1993, the Department of Housing and Urban Development offered financing

opportunities for geothermal development through its Community Development Block Grant Programs.

The Energy and Investment Tax Credits have been the most significant Federal tax advantages provided to the geothermal industry. Federal income tax provisions also allow portions of new plant capital investments to be written off for a specified recapture period, typically 5 years. However, the benefit of these credits in some cases is offset by the Alternative Minimum Tax enacted in 1987, under which the geothermal Energy Tax Credit is not allowed and geothermal property is depreciated over a longer period of time.

An income tax deduction reflecting resource depletion is allowed when determining the income from geothermal developments. Geothermal resources qualify for an annual percentage depletion allowance of 15 percent of the value of the resources sold, similar to the depletion allowance for oil and gas producers. Deductions for intangible drilling costs also are considered an important tax benefit for the geothermal industry. Another Federal incentive expected to significantly impact the geothermal industry is the 1.5-cent-per-kilowatthour (0.42-cent-per-megajoule) renewable energy production incentive authorized under the Energy Policy Act of 1992 (section 1212). This provision applies only to facilities owned by governments and other nonprofit entities, bringing to them an incentive mechanism commensurate with the tax incentives available to private developers.

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APPENDIX E

NEW PRODUCTION REACTORS CLOSEOUT

INTRODUCTION

The world situation today is much different than it was when in October 1988, DOE created the Office of New Production Reactors (NPR). The Department had shut down its last remaining production reactors for maintenance and safety upgrades, and NPR was to be responsible for providing the Nation with the new reactor capacity that it needed to ensure its supply of nuclear weapons materials, primarily tritium, in a safe and environmentally sound manner. In February 1991, the Department announced that it would prepare only one of its existing reactors for restart, the K reactor at the Savannah River Site.

On November 1, 1991, responding to revised estimates of the Nation's nuclear weapons requirements, DOE took the New Production Reactors Program off its urgent schedule and established a revised operational date of the year 2005. NPR also began to look at reducing the size of the production facility to reflect the lessened demand for tritium. The international events of 1992, including arms agreements between the United States and the former Soviet Union and the subsequent breakup of the Soviet Union, allowed the United States to further reduce the size of its nuclear weapons stockpile, meaning that the Nation would not require new tritium production capacity until almost 2010.

On October 19, 1992, the Secretary directed that DOE defer NPR efforts and bring all program activities to a prompt, orderly, and cost-effective closure. In accordance with that directive, and consistent with the 1992 Energy

and Water appropriation, the Department abolished the NPR Program effective March 7, 1993, and established a closeout team of six NPR employees to wrap up residual activities, such as files disposition, critical test completion, and financial reconciliations. All NPR employees (approximately 350), with the exception of the closeout team, were placed in positions in other areas of the Department, other Federal agencies, and private industry.

TECHNOLOGY AND SITE SELECTION

To accomplish its mission, NPR had planned to examine three technologies—a heavy-water reactor, a modular high-temperature gas-cooled reactor, and a light-water reactor—and three sites—the Savannah River Site in Aiken, South Carolina, the Idaho National Engineering Laboratory in Idaho Falls, Idaho, and the Hanford Site in Richland, Washington. During 1992, the office proceeded with the earlier decisions to delay the program, incorporate its environmental impact statement analysis into the Weapons Reconfiguration Programmatic Environmental Impact Statement, and reconsider the appropriate size for new production capacity. DOE also initiated a study on the possible use of accelerators to produce tritium. The programmatic environmental impact statement would have considered accelerators and would have added two more potential sites (Amarillo, Texas, and Oak Ridge, Tennessee) as part of the decision process.

SCHEDULING

NPR's 1992 activities would have led to an operational facility in the year 2005. With the reduction in the U.S. weapons stockpile, the need for new tritium capacity has moved closer to 2010.

REACTOR DESIGNS

Heavy-Water Reactor

NPR's design activities in 1992 for the heavy-water reactor involved downsizing the reactor by determining the impacts of various engineering modifications and recommending the most safe and cost-effective design, given the reduced production requirement. The office also focused on areas of high technical risk to minimize the likelihood that there would be any schedule delays resulting from foreseeable engineering problems, as well as on incorporation of advanced safety technology and on potential engineering and construction issues.

Light-Water Reactor

NPR completed its light-water reactor activities, except for some site cleanup and final reports. No 1993 funding

was required for this effort. The office provided final results of the tritium target development effort to the Assistant Secretary for Defense Programs.

Modular High-Temperature Gas-Cooled Reactor

All appropriate technology from the closed-out New Production Reactors Program was transferred to the Modular High-Temperature Gas-Cooled Reactor Program within the Office of Nuclear Energy.

CONCLUSION

For the foreseeable future, nuclear deterrence remains an essential element of the Nation's strategic defense policy. Because tritium, a radioactive isotope of hydrogen, is critical to maintaining the nuclear deterrent, and because tritium decays by about 5.5 percent each year, the ability to produce tritium is critical to maintaining the strategic deterrent. The Department remains responsible for ensuring a highly reliable, long-term supply of tritium.

APPENDIX F

SPACE-RELATED ACTIVITIES

INTRODUCTION

For more than 30 years, DOE has played a significant role in supporting the Nation's space programs. It has developed satellite instruments to verify compliance with arms control treaties, supplied nuclear power sources for long-duration space missions, provided world-class facilities for space radiation effects research, and performed advanced research and technology development for the Department of Defense (DOD) and the National Aeronautics and Space Administration (NASA).

In 1991, the Administration asked the Department to expand its support role in space to accomplish the goals of the Nation's space programs. To perform this expanded role, the Secretary of Energy appointed a Special Assistant for Space in March 1991 and established an Office of Space within the Office of the Department's Science and Technology Advisor that October. The office was responsible for developing departmental space policy and for coordinating space-related activities within the Department and with other Federal agencies, state and local governments, universities, and the commercial sector. It ensured that DOE space plans were consistent with national space policy and reflected the requirements of the civilian, national security, and commercial space sectors.

POLICY FORMULATION AND REVIEW

The Office of Space provided advice to the Secretary and to other officials within the Department on issues related

to departmental, national, and international space policy. To this end, the office represented the Department on the Nation's space committees, boards, and councils. For example, the Director of the Office of Space supported the Secretary of Energy's role as a member of the National Space Council (NSpC), participating in activities of the NSpC's Policy Implementation and Review Committee and in working groups to ensure that national space policy goals were being accomplished. He also represented the Department on DOD, NASA, and National Research Council boards and task forces concerning energy-related space activities.

In July 1992, Secretary of Energy Watkins signed a memorandum of understanding that (1) defined the appropriate role for the Department in supporting NASA's civil space mission and (2) established a streamlined process to coordinate and facilitate the activities of the two agencies. The agreement resulted in teams of representatives from both agencies concentrating on seven areas: space-based remote sensing, space radiation effects research, advanced space technology, high-performance computing, precursor missions, international space activities, and space nuclear power and propulsion. Within 2 months, the seven teams reviewed NASA space requirements and DOE capabilities and offered policy and program recommendations to a senior management review group representing the two organizations. Many of these recommendations were approved by the former Secretary and the NASA Administrator, enabling NASA to capitalize on the energy-related capability present within the Department's National Laboratories.

Also in 1992, the Department's Science and Technology Advisor initiated an interagency International Space Technology Assessment Program with DOD and NASA

to assess the availability and demonstrate the applicability of foreign space technology, facilities, and capabilities to energy-related areas of the Nation's space programs. The initial activities of the program focused on the capabilities within the former Soviet Union, with fact-finding trips concentrating on renewable energy, space radiation effects research, space nuclear power and propulsion, lasers and optics, and materials. The program is pursuing further detailed discussions in areas of special interest to NASA, DOD, and DOE, such as lasers and optics, with the goal of applying appropriate technologies to the Nation's space programs.

TECHNICAL PLANS AND ACTIVITIES

Working with appropriate DOE secretarial officers, the Office of Space promoted and developed cooperative and collaborative space ventures with DOD, NASA, and the commercial space sector to support the goals and objectives of the Nation's space programs. The office established technology areas that were consistent with the Department's missions in energy, national security, and science and technology, that applied the unique capabilities and resources of the national laboratories, and that dovetailed the committees established by the Federal Coordinating Council on Science, Engineering, and Technology. These technology areas were as follows:

1. Renewable energy, including in situ resource utilization and energy transmission, storage, and management
2. Human health and life sciences, including radiation effects
3. Environmental monitoring, including Earth and planetary observations, and both in-situ and remote sensing of planetary environments
4. Manufacturing and construction, including materials, robotics, and shielding
5. High-performance computing
6. Nuclear technologies, including power and propulsion
7. Mathematics and science education

These seven areas represent core competencies existing within the national laboratories that can be applied to develop the hardware required by NASA, DOD, and the commercial sector.

INTERAGENCY SUPPORT OF NASA'S MISSIONS

Mission to Planet Earth

The Department is active in several programs that focus on monitoring and defining the Earth's environment, such as the Strategic Environmental Research and Development Program (SERDP). In 1990, Senators Al Gore and Sam Nunn initiated SERDP to improve the coordination of long-term environmental research and development performed by DOD, DOE, and EPA. The program funds several space-related activities, such as the Joint DOD/DOE Atmospheric Remote Sensing and Assessment Program for Global Climate Change.

In 1992, a Presidential directive encouraged DOE to participate in an interagency effort to develop a space-based observation system that could aid policy makers in better understanding the effects of human and natural activities on the environment. The Department proceeded as directed. Specifically, the Department was asked to apply its advanced remote sensing and small satellite technologies, developed at the national laboratories, to the problem of space-based remote sensing in support of the U.S. Global Change Research Program, consistent with the recommendations of the Frieman Earth Observing System Engineering Review Panel. Under NASA leadership, DOE, DOD, and NASA worked together to develop a coordinated interagency space-based global change observing system plan. As part of the plan, DOE initiated development leading to deployment of two or three small satellites to measure the Earth's radiation. These satellites were designed to collect data on incoming solar radiation, radiation reflected from the Earth, and radiation reradiated from the Earth. In addition, DOE was encouraged by the policy directive to work with DOD and NASA to develop advanced technologies that offer the promise of lower cost and improved performance for future global change observing systems.

DOE sensors and various environmental data gathered through DOE programs also apply to NASA's Mission to Planet Earth for evaluating atmospheric composition, determining wind and ocean currents, and mapping changes in vegetation cover. In May 1992, Senator Gore and the director of the Central Intelligence Agency initiated an environmental task force to provide the scientific community with access to systems and environmental data that had been collected through classified sources. A group of approximately 60 distinguished U.S. scientists from the

environmental community were cleared for this task force. The task force was directed to provide a report that identifies space-related projects and demonstrations that affect the Department's defense, energy, intelligence, and environmental restoration and waste management missions.

Mission from Planet Earth

Working under the auspices of a Presidential directive, DOE provided program liaison and technical expertise to NASA headquarters and the associated centers to help define energy-related requirements and technologies for future manned exploration missions to the Moon and Mars. Personnel from the national laboratories supplied technical and analytical support for mission planning and development activities over a broad range of technical areas, identified and evaluated technical requirements related to space exploration that correspond to DOE's interests and capabilities, and provided NASA with access to the technologies, skills, and facilities existing within the DOE laboratory network. Laboratory personnel from the Argonne National Laboratory, the Brookhaven National Laboratory, the Idaho National Engineering Laboratory, the Lawrence Livermore National Laboratory, the Los Alamos National Laboratory, the National Renewable Energy Laboratory, the Oak Ridge National Laboratory, the Pacific Northwest Laboratory, and the Sandia National Laboratories were assigned to the National Exploration Office and its Exploration Program Office at the Johnson Space Center. The focus of their support was on the following technical areas:

1. Electrical and thermal power generation and management for in-space and planetary surface operation, including batteries, fuel cells, and solar and nuclear systems
2. Remote sensing to support the analysis of planetary atmospheres and surfaces, including the use of new and existing DOE lightweight sensors for observation, for the determination of elemental and mineralogical compositions and concentrations, and for topological mapping (Two DOE-developed sensors have been recommended for a candidate flight program for lunar orbiters.)
3. Radiobiological effects of naturally occurring space radiation
4. Robotic systems and planetary rovers, including teleoperated and fully automated systems

5. Advanced materials for strong, lightweight structures and high-precision, advanced manufacturing techniques

TECHNOLOGY TRANSFER

The Aerospace Industries Association, the National Center for Advanced Technology, the Department of Commerce, and the Office of Space hosted meetings of the commercial remote sensing community in Albuquerque in October 1992 and in Livermore, California, in March 1993. The participants included representatives from the association, the Department of Commerce, DOD, DOE, NASA, and industry. This effort evolved from the Department of Commerce's desire to capitalize on expertise and capabilities within the national laboratories and industry to demonstrate state-of-the-art technology that could commercialize remote sensing for a wide range of applications, such as agribusiness and environmental monitoring. Such an initiative would enable industry to develop improved remote sensing capability for the needs of both NASA and DOD. The effort is aimed at reducing the size, cost, and weight of remote sensing systems, while increasing their capability. These improvements, along with resulting increases in market viability, could spur a commercial remote sensing industry.

SPACE TECHNOLOGY INITIATIVE

The interagency Space Technology Interdependency Group (STIG) coordinated the research and development activities of the science and technology base required to support interagency space-related programs. In December 1991, DOE joined representatives of NASA, the U.S. Air Force, the U.S. Army, and the U.S. Navy on STIG, which provided a forum for personnel from participating Government agencies and their technical laboratories to develop cooperative relationships, to exchange technical information, and to identify new cooperative opportunities. The technology addressed by the STIG committees included: information collection, transfer, and processing; propulsion; power; flight dynamics and control; space structures; operations; space vehicle environments and effects; and in-space flight experiments. These technical committees meet periodically and report each year to a steering committee.

CLOSEOUT OF THE OFFICE OF SPACE AND THE TRANSFER OF FUNCTIONS

In 1993, the Secretary of Energy reorganized the Department to achieve a more efficient, streamlined organiza-

tion. The Office of Science and Technology Advisor, under which the Office of Space resided, was affected by the reorganization. In keeping with the role as Science and Technology Advisor to the Secretary, the Director of Energy Research became responsible for former Office of Space functions, which were incorporated into the Office of Energy Research.

LIST OF ABBREVIATIONS

AC	alternating current	AMS Program	Applied Mathematical Sciences Program
ACTS	Authorized Classifiers Tracking System	ANL-W	Argonne National Laboratory-West
AD	Office of Administration and Human Resource Management	APA	Alaska Power Administration
AEA	Atomic Energy Act of 1954	API	American Petroleum Institute
AEC	Atomic Energy Commission	ARIES	Advanced Reactor Innovations Evaluation Study
AEP	Division of Advanced Energy Projects	ARM Program	Atmospheric Radiation Measurement Program
AGS	Alternating Gradient Synchrotron	ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
AIDS	acquired immune deficiency syndrome	ATTAP	Advanced Turbine Technology Application Program
AIP	agreement in principle	AVLIS	<i>see</i> U-AVLIS
ALARA	as low as reasonably achievable	BATS	Biweekly Action Tracking System
Alcoa	Aluminum Company of America	bcf	billion cubic feet
ALMR	advanced liquid-metal reactor	bcm	billion cubic meters
ALWR	advanced light-water reactor	BER Program	Biological and Environmental Research Program
AMFA	Alternative Motor Fuels Act of 1988	BES Program	Basic Energy Sciences Program
A/mm ²	amperes per square millimeter		

LIST OF ABBREVIATIONS

BPA	Bonneville Power Administration	CHAMMP Program	Computer Hardware, Advanced Mathematics, and Model Physics Program
Btu	British thermal unit		
C	Celsius	COCOM	Coordinating Committee on Multilateral Controls
CAAA	Clean Air Act Amendments of 1990	COG program	Continuity of Government program
CADDET	Center for the Analysis and Dissemination of Demonstrated Energy Technologies	CORECT	Committee on Renewable Energy Commerce and Trade
CAFS	Classification Appraisal Follow-up System	CORRTEX	Continuous Reflectometry for Radius Versus Time Experiment
CAREIRS	Conservation and Renewable Energy Inquiry and Referral Service	CR	Office of Chief Financial Officer
CAT	computer-assisted tomography	CRADA	cooperative research and development agreement
CATS	Computerized Action Tracking System	CRAF	Comet Rendezvous Asteroid Flyby
CBECS	Commercial Buildings Energy Consumption Survey	D&D	decontamination and decommissioning
CE	Office of Conservation and Renewable Energy	DAR	direct absorption receiver
CEDR	Comprehensive Epidemiologic Data Resource	DASMA	Deputy Assistant Secretary for Military Application
CEQ	Council on Environmental Quality	DEM, Inc.	Dreisbach Electromotive, Inc.
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980	DHW	domestic hot water
CERN	European Center for Nuclear Research	DIII-D	Doublet III-D
CFC	chlorofluorocarbon	DISCAS	Departmental Integrated Standardized Core Accounting System
CFC-12	dichlorodifluoromethane	DNA	deoxyribonucleic acid
CFO	Chief Financial Officer	DOD	Department of Defense
CFR	Code of Federal Regulations	DOE	Department of Energy
		DOE/NIPER	Department of Energy/National Institute for Petroleum and Energy Research

DP	Office of Defense Programs	ESAR	Energy Situation Analysis Report
DSM	demand-side management	ESF	emergency support function; Exploratory Studies Facility
DSTA	Deputy Science and Technology Advisor	ESnet	Energy Sciences network
EA	environmental assessment	ESP	Electric Service Priority
EBR-II	Experimental Breeder Reactor-II	ESRA	Envelope Systems Research Apparatus
EEO	equal employment opportunity	ETTP	Enhanced Technology Transfer Program
EES	Energy Extension Service		
EH	Office of Environment, Safety, and Health	Euratom	European Atomic Energy Community
EIA	Energy Information Administration	F	Fahrenheit
EIS	environmental impact statement	FCF	Fuel Cycle Facility
EM	Office of Environmental Restoration and Waste Management	FDS	funds distribution system
EMF	electromagnetic field	FeCN	ferrocyanide
EMS	emergency management system	FEMA	Federal Emergency Management Agency
EMW Program	Energy from Municipal Solid Waste Program	FEMP	Federal Energy Management Program; Fernald Environmental Management Project
ENPEP	Energy and Power Evaluation Program	FERC	Federal Energy Regulatory Commission
EOC	Emergency Operations Center	FFTs	Fast-Fourier Transforms
EOI	emergency operating instruction	FINESSE	Financing Energy Services for Small- Scale Energy Users
EPA	Environmental Protection Agency	FOCI	Foreign Ownership, Control, or Influence Program
ER	Office of Energy Research	FR	<i>Federal Register</i>
ERA	Economic Regulatory Administration	FTTA	Federal Technology Transfer Act
ERIP	Energy-Related Inventions Program	FUSRAP	Formerly Utilized Sites Remedial Action Project
ES&H	environmental, safety, and health; Environmental, Safety, and Health Program		

LIST OF ABBREVIATIONS

GCM	general circulation model	IE-DO	International Affairs and Energy Emergencies Duty Officer
GOCO	Government owned, contractor operated	IFR	integral fast reactor
GOGO	Government owned, Government operated	IG	Inspector General
GPO	Government Printing Office	IN	Office of Intelligence
GSA	General Services Administration	InnCon	Innovative Concepts Program
GS/GM	General Schedule/General Merit	IRM	Information Resources Management
GW	gigawatt	IRP	integrated resource planning
HEU	highly enriched uranium	IRTS	Integrated Radwaste Treatment System
HGP	Human Genome Program	ITEP	International Technology Exchange Program
HHS	Department of Health and Human Services	ITER	International Thermonuclear Experimental Reactor
HIFAR Program	Heavy Ion Fusion Accelerator Research Program	JGOFS	Joint Global Ocean Flux Study
high- T_c	high temperature superconducting	JVD	Jet Vapor Deposition
HPCC Initiative	High Performance Computing and Communications Initiative	KCP	Kansas City Plant
H.R.	House bill	kW	kilowatt
HTS	high-temperature superconductivity	LANL	Los Alamos National Laboratory
HUD	Department of Housing and Urban Development	LASCAR	Large Scale Reprocessing Plant Safeguards project
HWR	heavy-water reactor	LBL	Lawrence Berkeley Laboratory
IAEA	International Atomic Energy Agency	LDR	Land Disposal Restrictions
IAQ	indoor air quality	LLNL	Lawrence Livermore National Laboratory
ICF	Inertial Confinement Fusion	LLRWPA	Low-Level Radioactive Waste Policy Amendments Act
ICP	Institutional Conservation Program	LWR	light-water reactor
IEA	International Energy Agency	M&O	management and operating

MED	Manhattan Engineer District	NCMS	National Center for Manufacturing Sciences
Mega-NOPR	notice of proposed rulemaking on natural gas pipeline reform	NCS	National Communications System
METC	Morgantown Energy Technology Center	NCTTA	National Competitiveness Technology Transfer Act
MHD	magnetohydrodynamics	NDER	National Defense Executive Reserves
MHTGR	modular high-temperature gas-cooled reactor	NEA	Nuclear Energy Agency
MI	Office of Minority Economic Impact	NEIC	National Energy Information Center
MIT	Massachusetts Institute of Technology	NEPA	National Environmental Policy Act
MMBD	million barrels per day	NERSC	National Energy Research Supercomputer Center
MOU	memorandum of understanding	NES	National Energy Strategy
MRS	monitored retrievable storage	NIH	National Institutes of Health
MSIS	Management Systems Improvement Strategy	NMMSS	Nuclear Materials Management and Safeguards System
MSW	municipal solid waste	NNPA	Nuclear Non-Proliferation Act of 1978
MW	megawatt	NOAA	National Oceanic and Atmospheric Administration
NAM	National Association of Manufacturers	NOSR	Naval Oil Shale Reserve
NAPAP	National Acid Precipitation Assessment Program	NO _x	nitrogen oxide
NASA	National Aeronautics and Space Administration	NPHMP	natural phenomena hazards mitigation programs
NATAS	National Appropriate Technology Assistance Service	NPR	Naval Petroleum Reserve; New Production Reactor; Office of New Production Reactors
NATO	North Atlantic Treaty Organization	NPT	Treaty on the Non-Proliferation of Nuclear Weapons
NBL	New Brunswick Laboratory	NRC	Nuclear Regulatory Commission
NCAR	National Center for Atmospheric Research	NREL	National Renewable Energy Laboratory

LIST OF ABBREVIATIONS

NS	Office of Nuclear Safety	OTA	Office of Threat Assessment
NSR	New Special Recovery facility	OTD	Office of Technology and Development
NTI	National Technology Initiative	OTFA	Office of Technical and Financial Assistance
NTIS	National Technical Information Service (Department of Commerce)	PC	personal computer
NWC	Nuclear Weapons Council	PCB	polychlorinated biphenyl
NWPA	Nuclear Waste Policy Act of 1982	PEDRO	Petroleum Electronic Data Reporting Option
OBT	Office of Building Technologies	PEIS	programmatic environmental impact statement
OCRWM	Office of Civilian Radioactive Waste Management	PEM	proton-exchange membrane
OEA	Office of Export Assistance	PET	positron emission tomography
OECD	Organization for Economic Cooperation and Development	PETC	Pittsburgh Energy Technology Center
OEE	Office of Energy Emergencies	PMA	power marketing administration
OGC	Office of General Counsel	PNC	Power Reactor and Nuclear Fuel Development Corporation of Japan
OHAO	Office of Headquarters Accounting Operations	PNL	Pacific Northwest Laboratory
OIG	Office of Inspector General	POTAS	Program of Technical Assistance to IAEA Safeguards
OIT	Office of Industrial Technologies	PR	Office of Procurement, Assistance and Program Management
OMB	Office of Management and Budget	PRISM	Power Reactor Innovative Small Module
OPSEC	Operations Security Program	PRL	Michigan State University Plant Research Laboratory
ORNL	Oak Ridge National Laboratory	PSO	Program Secretarial Officer
ORTA	Office of Research and Technology Applications	PTN	Prototype Training and Networking Program
OSH Program	Occupational Safety and Health Program	PUHCA	Public Utility Holding Company Act
OSHA	Occupational Safety and Health Administration		
OSS	Office of Safeguards and Security		

PV	photovoltaic	SERAP	The Socioeconomic Research and Analysis Program
PVM	Parallel Virtual Machine	SES	Senior Executive Service
PVMaT project	Photovoltaic Manufacturing Technology project	SHOPP	State Heating Oil and Propane Program
PVUSA	Photovoltaics for Utility-Scale Applications	SLC	Stanford Linear Collider
QA	quality assurance	SNL	Sandia National Laboratories
quad	quadrillion British thermal units	SNM	special nuclear materials
R&D	research and development	SNRB	SO _x -NO _x -Rox-Box
<i>RadCon Manual</i>	<i>Radiological Control Manual</i>	SO ₂	sulfur dioxide
RCRA	Resource Conservation and Recovery Act	SPR	Strategic Petroleum Reserve
RD&T	research, development, and testing	SQUID	Superconducting QUantum Interference Device
RF	radiofrequency	SRS	Savannah River Site
RFP	Rocky Flats Plant	SSC	Superconducting Super Collider
ROD	Record of Decision	SSCL	Superconducting Super Collider Laboratory
R.O.K.	Republic of Korea	SSRR	safeguards and security readiness review
RTG	radioisotope thermoelectric generator	STA	Science and Technology Advisor
R-value	thermal resistivity	SWU	separative work unit
S.	Senate bill	TES	thermal energy storage
SBH	sequencing by hybridization	TESS	TRW Environmental Safety Systems, Inc.
SBIR Program	Small Business Innovation Research Program	TFTR	Tokamak Fusion Test Reactor
SDIO	Strategic Defense Initiative Organization	TRAIN	TRansportation Assessment and INtegration
SECP	State Energy Conservation Program	TRANSAX	Transportation Accident Exercise Program
SEN	Secretary of Energy notice		

LIST OF ABBREVIATIONS

TSCM	Technical Surveillance Countermeasures Program	UNSCOM	United Nations Special Commission
TTAC	Technology Transfer Advisory Committee	UNSCR	United Nations Security Council Resolution
TTBT	Threshold Test Ban Treaty	USABC	United States Advanced Battery Consortium
TTFTF	Technology Transfer Field Task Force	U.S.C.	United States Code
TTPG	Technology Transfer Program Group	VOC	volatile organic compound
U-235	uranium-235	WAP	Weatherization Assistance Program
U-238	uranium-238	WEPCO	Wisconsin Electric Power Company
U ₃ O ₈	uranium yellow cake	WIPP	Waste Isolation Pilot Plant
U-AVLIS	uranium-atomic vapor laser isotope separation	WOCE	World Ocean Circulation Experiment
U-value	thermal performance measure	WRD&T	Weapons Research, Development, and Testing program
UCLA	University of California, Los Angeles	ZIP	ZIP Code Insulation Program
UCNI	Unclassified Controlled Nuclear Information		
UEE	Uranium Enrichment Enterprise		