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ORNL TRENDS & BALANCES 1987-1992

January 1987

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Cover: These small gel beads (1 mm in diameter) act as catalysts in a fluidized-bed system developed at ORNL for producing fuel alcohol from corn sugars.

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Acronyms

ACTO	Advanced Control Test Operation	FTE	full-time equivalent
AGS	Alternating Gradient Synchrotron	HASRD	Health and Safety Research Division
ANL	Argonne National Laboratory	HBCU	Historically Black Colleges and Universities
ASM	advanced servomanipulator	HERMIES	Hostile Environment Robotic Machine Intelligence Experiment Series
ATF	Advanced Toroidal Facility	HFIR	High Flux Isotope Reactor
BNL	Brookhaven National Laboratory	HHIRF	Holifield Heavy Ion Research Facility
BTESM	Building Thermal Envelope Systems and Materials	HILI	Heavy Ion/Light Ion
CBCF	carbon-bonded carbon fiber	HISTRAP	Heavy-Ion Storage Ring for Atomic Physics
CEUSP	Consolidated Edison Uranium Solidification Program	HLW	high-level waste
CDIC	Carbon Dioxide Information Center	HMW	hazardous and mixed waste
CESAR	Center for Engineering Systems Advanced Research	HPRR	Health Physics Research Reactor
CFRP	Consolidated Fuel Reprocessing Program	HTGR	high-temperature gas-cooled reactor
CIT	Compact Ignition Tokamak	HTML	High Temperature Materials Laboratory
CNR	Center for Neutron Research	IAEA	International Atomic Energy Agency
CWDF	Central Waste Disposal Facility	IBD	Ion Beam Deposition
D&T	development and technology	IET	Integrated Equipment Test
DIID-D	Doublet III-D tokamak	IFSMTF	International Fusion Superconducting Magnet Test Facility
DOD	Department of Defense	INTOR	International Tokamak Reactor
DOE	Department of Energy	JAERI	Japan Atomic Energy Research Institute
DOI	Department of the Interior	LANL	Los Alamos National Laboratory
DOT	Department of Transportation	LCP	Large Coil Program
DP	defense program	LLNL	Lawrence Livermore National Laboratory
DPI	Deuterium Pellet Injector	LLW	low-level waste
EBT	Elmo Bumpy Torus	LMR	liquid metal reactor
ECUT	Energy Conversion and Utilization Technologies	LWR	light-water reactor
EH&S	environmental, health, and safety	MHTGR	modular high-temperature gas-cooled reactor
EIS	Environmental Impact Statement	NASA	National Aeronautics and Space Administration
EPA	Environmental Protection Agency	NAVFAC	Naval Facilities Engineering Command
EPRI	Electric Power Research Institute	NCSASR	National Center for Small-Angle Scattering Research
ESD	Environmental Sciences Division	NEESA	U.S. Naval Energy and Environmental Support Activity
FDA	Food and Drug Administration	NERP	National Environmental Research Park
FEDC	Fusion Engineering Design Center	NRC	Nuclear Regulatory Commission
FEMA	Federal Emergency Management Agency	NSF	National Science Foundation

NSLS	National Synchrotron Light Source	RPI	Repeating Pneumatic Injector
OCRWM	Office of Civilian Radioactive Waste Management	RPP	Radiochemical Processing Plant
OER	Office of Energy Research	SCO	Support Contractor Office
OHER	Office of Health and Environmental Research	SCSS	Sequence Coding and Search System
ORAU	Oak Ridge Associated Universities	SDI	Strategic Defense Initiative
ORELA	Oak Ridge Electron Linear Accelerator	SMAC	Surface Modification and Characterization
ORNL	Oak Ridge National Laboratory	STX	Spherical Torus Experiment
ORO	Oak Ridge Operations	TEXTOR	Tokamak Experiment for Technical Oriented Research
OTA	Office of Technology Applications	TFTR	Tokamak Fusion Test Reactor
PNC	Power Reactor and Nuclear Fuel Development Corporation (Japan)	TPP	Transuranium Processing Plant
PPPL	Princeton Plasma Physics Laboratory	TRU	transuranic
PWTP	Process Waste Treatment Plant	TURF	Thorium-Uranium Recycle Facility
R&D	research and development	ULCP	University Laboratory Cooperative Program
RAP	Remedial Action Program	UTK	University of Tennessee at Knoxville
RCS	Residential Conservation Service	WFO	work for others
RFTF	Radio Frequency Test Facility	WIPP	Waste Isolation Pilot Plant
RH	remotely handled	WMTC	Waste Management Technology Center

Preface

This is the ninth edition of *Trends & Balances*, which is presented to the staff of Oak Ridge National Laboratory (ORNL) and other interested persons.

The Oak Ridge National Laboratory *Institutional Plan*, issued each year at the end of the planning cycle, is the official planning document for the Laboratory. The *Institutional Plan* is a detailed and extensive projection of the operational and programmatic directions the Laboratory will take for the subsequent six years. *Trends & Balances* provides a condensed insight into the capabilities, expertise, and potential of the resources at ORNL.

As happens with most large institutions, major changes in objectives and directions at ORNL happen slowly over extended periods of time. Therefore, much of the information in this document is updated from previous editions. Some information, however, is different and represents major new Laboratory initiatives. Programmatic budget outlay and personnel projections for the planning period are presented in the bar charts throughout the document.

The planning and administrative members of ORNL have become increasingly aware of the projected trends in public perception of federal support of basic, applied, and developmental energy-related research and development (R&D). This awareness has propagated the realization that R&D laboratories administered by the U.S. Department of Energy (DOE) are truly national resources and centers of excellence that should be used and supported to serve all sectors of government, industry, and universities.

Mark W. Sollenberger
Program Planning and
Analysis Office
January 1987

Director's Statement

The decade of the eighties has brought significant changes to the roles and priorities of the Department of Energy and to the activities of the Department's national laboratories, including Oak Ridge National Laboratory (ORNL). These changes were driven by three primary influences. First, government sponsorship of any technology development of near-term commercial applicability runs counter to the current political philosophy. Next, the world oil glut took away much of the urgency associated with the development of new energy technologies. Finally, the mounting federal budget deficit has put exceptional pressure on all federal nondefense programs.

As a consequence of these three influences, R&D on energy technologies is almost nonexistent; no demonstration facilities are being planned for any area of energy—not in solar, fission, fusion, conservation, or fossil. Many large demonstrations, particularly in synthetic fuels, have been canceled. On the other hand, the sciences and base technologies that provide the foundation for new energy technologies have continued steadily.

The one certainty about the future is that it will be different from the present. In 1988, a new administration will set new, but as yet unknown priorities. In the next three

to five years, the federal budget deficit issue is likely to have far less bite and influence. Most analysts agree that by the mid-1990s energy constraints will again become a high-profile topic. Most important, there is a growing consensus that if the United States is to meet the challenge of global economic competition, the nation must call upon all of its intellectual resources—universities, industry, and national laboratories—to work together in new ways.

Over the next 15 years, the direction and motivation of the Laboratory will derive from two themes—energy and global competition. Energy production, environmental consequences, and conservation will remain very important issues for the United States in the foreseeable future. Research, development, and demonstration associated with energy production and conservation, as well as basic research in both the physical and life sciences supporting those technologies, will remain the backbone of work at ORNL during this planning period.

The ability of the United States to be innovative and thus to remain competitive in ever-increasing global competition will be an equally important task. Those countries that can most quickly turn innovative ideas into desirable goods will be the

winners. Thus, the ability of ORNL to utilize results from its energy work to keep the United States competitive globally will be a strong goal for us during this long-term planning period. Maintaining leadership in energy research and increasing U.S. competitiveness will challenge ORNL to become more involved and more collaborative than in the past and will require us to look for new areas of collaborative research and new ways of moving technological innovations to the marketplace.

From its earliest days, the Laboratory has worked hard to transfer technology and to collaborate fully with others. Reactor technology was transferred to Hanford, results of fuel cycle research to Idaho and Savannah River, nuclear submarine reactor technology to Idaho, and civilian reactor technology to the world through the Oak Ridge School of Reactor Technology. That collaboration has continued over the decades as marked by the extensive use of subcontractors, creation of user facilities, and exchanges of personnel. Recent collaborative efforts include the development of the Tokamak Fusion Test Reactor with Princeton, collaboration with several nations on the International Fusion Superconducting Magnetic Test Facility, work with several universities to optimize biomass production, and

collaboration with industry on heat pump technology. The combination of technology transfer, consortia, and collaboration will make the operation of ORNL even more complex than it is now; however, this broad scope is essential to our national role, and the Laboratory will continue to seek new partnerships, new ways, and new missions.

A handwritten signature in black ink, reading "Herman Postma". The script is fluid and cursive, with the first letter of each word being capitalized and prominent.

Herman Postma
Director

Laboratory Overview

Laboratory Roles

R & D Activities

The primary role of Oak Ridge National Laboratory (ORNL) is to support work in the energy technologies using applied research and engineering development in fusion, fission, and other energy technologies and scientific research in basic physical and life sciences. A secondary role of the Laboratory is to use its resources to help solve other nationally important problems, such as hazardous and chemical wastes, and to add to U.S. nonnuclear defense technology when such work is closely related to its primary role. In addition, ORNL designs and provides research facilities for the benefit of members of the scientific and technical community and supplies radioactive and stable isotopes that are not available from the private sector. Major ORNL sponsors are listed in Table 1.

To fulfill its missions, ORNL focuses its scientific and technical efforts on (1) magnetic fusion, with emphasis on applied plasma physics, experimental and design studies of confinement configurations, development of plasma heating and fueling systems and superconducting confinement magnets, and testing of candidate first-wall and blanket

materials; (2) nuclear fission, with emphasis on development of nuclear fuel reprocessing, materials testing and development for high-temperature gas-cooled reactors (HTGRs) and advanced converter reactors, and technologies for managing nuclear and chemical waste; (3) biological and environmental basic and applied research, with emphasis on interaction of energy-related physical and chemical agents with living organisms; (4) conservation and renewable energy, with emphasis on generic research for high-temperature materials, power systems, biomass production, energy storage, and technology development for buildings and industry; (5) fossil energy, with emphasis on materials, environmental control technologies, and environmental health and safety research; and (6) basic research in physical sciences, with emphasis on materials research, high-temperature materials, neutron scattering, and surface physics; in chemical sciences on analytic and separation techniques, atomic physics and high-temperature aqueous chemistry, and in nuclear physics on heavy-ion reactions. In addition, ORNL interacts frequently with scientific and technical personnel in universities and industry.

ORNL builds and maintains research facilities for the benefit of

members of the scientific and technical community. Thirteen user research facilities are now available at ORNL for use by outside experimenters. Three new facilities constructed in 1986 are the High Temperature Materials Laboratory, the Roof Research Center, and the Low Temperature Neutron Irradiation Facility. The balance of these facilities includes the EN-Tandem Van de Graaff Accelerator, the Oak Ridge Electron Linear Accelerator, the Shared Research Equipment Collaborative Research Program, the Oak Ridge National Environmental Research Park, the National Center for Small-Angle Scattering Research, the Holifield Heavy Ion Research Facility, the Surface Modification and Characterization Collaborative Research Laboratory, the Neutron Scattering Facility, the Health Physics Research Reactor, and the Bioprocessing Research Facility. During FY 1986, about 700 scientists from around the world performed experiments at ORNL user facilities.

In addition to these activities for the U.S. Department of Energy (DOE), ORNL does work for other federal agencies, state and local governments, private concerns, and foreign governments. The Laboratory performs this work for others (WFO)

Table 1. Current ORNL sponsors

DOE sponsors

- DOE
 - Office of Energy Research
 - Assistant Secretary for Nuclear Energy
 - Assistant Secretary for Conservation and Renewable Energy
 - Assistant Secretary for Defense Programs
 - Assistant Secretary for Fossil Energy
- Other DOE
 - DOE Contractor and Operations Office
 - Environment, Safety, and Health
 - Federal Energy Regulatory Commission
 - Economic Regulatory Administration
 - Energy Information and Administration
 - Office of Policy Planning and Analysis
 - Office of Civilian Radioactive Waste Management
 - Management and Administration

Other sponsors

- Nuclear Regulatory Commission
 - Other federal agencies
 - Department of Defense
 - Department of Health and Human Services
 - Environmental Protection Agency
 - Federal Emergency Management Administration
 - Tennessee Valley Authority
 - Department of Transportation
 - National Science Foundation
 - Other nonfederal agencies
 - Electric Power Research Institute
- Other nonfederal agencies

in areas of significant expertise that are consistent with the interests of DOE. The majority of this work for others is performed for the Department of Defense (DOD) and the Nuclear Regulatory Commission

(NRC). While Laboratory work for DOD is rapidly increasing, work for NRC is slowly declining. Other major federal users of ORNL are the Department of Health and Human Services (DHHS), the Environmental

Protection Agency (EPA), the National Science Foundation (NSF), and the Federal Emergency Management Agency (FEMA).

ORNL has a demonstrated commitment to increase the involvement of university personnel in its R&D activities. This is imperative to ensure the supply of well-trained, qualified technical personnel for the future. The Laboratory is assisting DOE to achieve this goal by providing opportunities for students for training and participation in research projects and by encouraging students to attend graduate school in energy-related disciplines.

Non-R & D Activities

Many of the stable and radioactive isotopes used throughout the world for peaceful purposes are produced at the Laboratory. ORNL is the only supplier for the majority of stable isotopes used in the western world. Each year roughly twenty million patients rely on ORNL-produced radioisotopes for radiotracer studies and therapeutic localized radiation treatments. One radioisotope of considerable recent interest, ^{153}Gd , is being used for noninvasive bone densitometry and the diagnosis of osteoporosis.

A Technology Transfer Program that began at ORNL in 1970 is today a growing program structured to satisfy the requirements of the Stevenson-Wydler Technology Innovation Act of 1980. The Act requires that federal agencies receiving R&D funds use 0.5% of those funds to transfer developed technology to private industry and assist state and local governments in their use of technology.

The Office of Technology Applications has been successful in assigning exclusive license rights to seven ORNL technologies. Accomplishments of the Technology Transfer Program are found in "Recent Achievements."

Jack Adams of Operations Division operates a high-pressure ion-exchange column as a part of the final purification step in producing greater than 99.999% radiochemically pure ^{153}Gd , a radioisotope used in the measurement of bone density for assessing osteoporosis. The increased use of ^{153}Gd has resulted in an expanded production effort for this radioisotope at ORNL, which is the sole supplier of this material.

Laboratory Organization

As evidenced by the Laboratory organization chart (Fig. 1), the Laboratory Executive Director and each Associate Director (AD) may be responsible for the execution of work funded by other federal and nonfederal agencies as well as that specified and provided by DOE.

The Laboratory Executive Director is R. S. Wiltshire. Divisions that report to him are Environmental and Occupational Safety, Finance and Materials, Health, Instrumentation and Controls, Laboratory Protection, Operations, Personnel, and Plant and Equipment. Centralized quality assurance activities report to Mr. Wiltshire through the Quality Department.

The AD for Nuclear and Engineering Technologies is F. R. Mynatt, who is responsible for the Chemical Technology, Engineering Technology, and Fuel Recycle divisions. His major program responsibilities include the Reactor, Consolidated Fuel Reprocessing, NRC, and Nuclear and Chemical Waste programs. He is also responsible for the administration of the DOD and Strategic Defense Initiative (SDI) work assigned to ORNL. Primary funding for DOE programs in Mynatt's areas comes from the Assistant Secretary for Nuclear Energy, with the Assistant Secretary for Defense Programs providing funding for nuclear waste management. Additional sources of funding are received from the Office

of Civilian Radioactive Waste Management and other federal and nonfederal agencies.

M. W. Rosenthal, the AD for Advanced Energy Systems, is responsible for the Energy and Fusion Energy divisions at ORNL. He is also responsible for Conservation and Renewable Energy and the Fossil Energy programs. Divisional and programmatic funding in his area is very diverse. The Assistant Secretary for Conservation and Renewable Energy, the Assistant Secretary for Fossil Energy, and the Office of Energy Research provide the major sources of funding in these areas. However, other federal and nonfederal agencies (such as the Energy Information Administration; the Office of Policy, Planning, and Analysis; the Federal Energy Regulatory Commission; the Federal Emergency Management Agency; and the Gas Research Institute) also provide sources of programmatic funding.

The AD for Biomedical and Environmental Sciences programs is C. R. Richmond. His responsibilities include the Biology, Environmental Sciences, and the Health and Safety Research divisions. He also directs the University Relations programs. The largest single source of funding for Biomedical and Environmental Sciences comes from the Office of Energy Research (OER). Other sources of funding include the Assistant Secretary for Environment, Safety, and Health; the EPA; and several other federal and nonfederal sources.

A. Zucker is the AD responsible for the division and programs performing research in Physical Sciences. These responsibilities include research and services provided by the Analytical Chemistry, Chemistry, Engineering Physics and Mathematics, Metals and Ceramics, Physics, and Solid State divisions. The Center for Neutron Research (CNR), which is a major new

Fig. 1. ORNL organization chart.

initiative for ORNL, is also Zucker's responsibility. The Physical Sciences activities at ORNL are primarily funded by the OER. However, other federal and nonfederal sources provide approximately 6% of the total funding for Physical Sciences programs.

R&D Sponsors

As noted in Fig. 2, DOE provided over 77% of the total ORNL R&D funding for FY 1986. The NRC and work for other federal and nonfederal agencies account for the balance of the total R&D funding.

Of the total funds provided by DOE, over 54% come from OER. Over 85% of these OER funds are directed toward research and services in the areas of Magnetic Fusion, Health and Environmental Research, and Basic Energy Sciences. The balance of the OER funding supports multiprogram Laboratory Facilities Support, Nuclear Physics, Energy Research Analysis, and University Research Support. Four other primary DOE sponsors—the Assistant Secretaries for Nuclear Energy, Conservation and Renewable Energy, Defense Programs, and Fossil Energy—account for an additional 38% of the total DOE funding. The balance of the total DOE funding is provided by DOE contractors and operations offices.

The largest non-DOE or DOE-related sponsor is DOD (Fig. 2), which provided approximately 9.8% of the total ORNL R&D support during FY 1986. Work for DOD includes nonnuclear defense technologies and waste R&D.

As shown in Figs. 3 and 4, the Fission Energy and Physical Sciences programs represent the two largest program areas at ORNL. However, the opportunity to perform R&D activities and provide services for sponsors other than DOE and to contribute to programs other than those listed as major ORNL

* PROGRAMMATIC ASSISTANT SECRETARY

Fig. 2. ORNL program funding sources by sponsor for FY 1986 (Total: FY 1986 budget outlay = \$377 million).

* PROGRAMMATIC ASSISTANT SECRETARY

Fig. 3. ORNL program funding sources by program for FY 1986.

programs has strengthened and broadened the technical talent at the Laboratory.

The primary program sponsors and the comparative contributions to the major ORNL programs can be seen in Figs. 2-5.

Recent Achievements

In 1986 many programs and projects have reached significant milestones toward achieving overall program goals, and many ORNL scientists have received awards and

FY 1986
Total: \$377 million

Fig. 4. Distribution of ORNL operating funds by program for FY 1986.

recognition for their contributions to these programs. The following sections highlight major research milestones, list outstanding personal achievements, and outline innovative administrative activities.

R & D Highlights

A new **Robotics and Intelligent Systems Program (RISP)** has been established to integrate ORNL's work in the areas of robotics, teleoperations, and related intelligent machines. The program will include all robotics activities for the Departments of Energy and Defense, NASA, and other sponsors. It is expected that activities regarding robotics and related intelligent systems will continue to grow at ORNL.

A compact portable instrument was assembled that could have a major impact on **explosives detection methods**. This instrument permits real-time detection of common

FY 1986
TOTAL: \$377million

FY 1986
TOTAL: 2240 DIRECT FTEs

Fig. 5. Total ORNL budget outlay and full-time equivalent distribution by sponsor for FY 1986.

explosives in ambient air at ppb sensitivities.

Construction and assembly of the **irradiation cryostat** were completed. A liquid-helium refrigeration system was operated for the completed cryostat and met design characteristics. The cooldown time for the cryostat was 4 h (as designed), and the refrigeration capacity of 4 K was adequate to remove the reactor heating in a 100-g irradiation experiment.

High-energy photons were produced in heavy-ion nuclear reactions and unambiguously identified in a lead-glass Cherenkov detector array. The measured gamma-ray distributions cannot be explained within a previously proposed statistical model or a nucleon-nucleon bremsstrahlung mechanism. The data indicate a more coherent production mechanism reflecting the direction of relative motion of target and projectile.

A first-principles theory was developed for the **calculation of the electrical resistivity of random alloys**. The theory requires no adjustable parameters and is applicable even to systems so disordered that energy bands no longer exist. The calculated resistivities for copper-zinc alloys are indistinguishable from experimental results. No useful resistivity theory existed previously for highly disordered systems.

A procedure was developed for the **efficient use of a hypercube computer**. The improvement in message passing among multiple processors allows the use of 90% of theoretical capability, making it the first direct-method solver to achieve such a high percentage with a large number (64) of processors. This method is expected to be widely adopted by hypercube computer users.

A combination of experimental chemical kinetics studies and computer-based geochemical modeling established a novel **mechanism for the**

primary migration of natural gas as acetate. This study answers long-standing questions associated with the formation, mobility, and accumulation of natural gas in the shallow water-saturated portions of sedimentary basins.

The first direct measurements of **melt-solid interface temperatures** and lattice temperature profiles under conditions of ultra-rapid melting and crystallization have been made in silicon by utilizing the pulsed time structure of synchrotron X rays. The results provide new information on the kinetics of melting and crystallization in silicon.

Some human genetic diseases that have been assumed to result from single gene mutations are probably caused instead by exchanges of portions of chromosomes. Using mice, researchers demonstrated for the first time that a **reciprocal chromosome translocation** can cause an inherited disease.

A **scanning-tunneling electron microscope** capable of single-atom resolution was successfully constructed. This instrument may make major contributions to understanding the microstructure of biological systems.

Recent synthesis of 18 years of research on **Walker Branch Watershed** demonstrated the value of long-term research in providing knowledge to resolve major environmental problems, such as acidic precipitation and shallow-land burial. Data from long-term studies such as this provide baseline information for comparing future changes and parameters for predictive models.

People of different genetic backgrounds probably differ in sensitivity to ethylene oxide. The importance of **genetic sensitivity** and resistance was demonstrated in an experiment in which mice of one

genetic strain could tolerate inhalation of 255 ppm for 50 days, but mice of another genetic strain became sterile after 5 days. Protection standards for ethylene oxide exposures will have to be changed.

Researchers took advantage of a unique opportunity to **measure Chernobyl-derived fission products** in atmospheric aerosols. Data were used to test submicron aerosol growth-rate models. The fission products' growth supports the model that diameter growth rate is controlled by reactions at the aerosol surface.

A new **sulfhydryl malicimide radiolabeled compound** for blood studies was developed. The new agent will be used by clinical collaborators at Temple University and Massachusetts General Hospital for studying the early events in plaque formation and other artery diseases.

A new field of **teratologic research** has been opened by the discovery in mice that congenital defects can be caused by exposure of the recently fertilized egg to environmental chemicals. To prevent abnormal human babies, women will have to be protected from teratogenic chemicals at the time of conception, as well as during fetal development.

ORNL has initiated and nearly brought to fruition a collaborative agreement with Japan's Power Reactor and Nuclear Development Corporation (PNC) in the area of **consolidated fuel reprocessing**. The broad framework for this five-year multimillion dollar R&D effort was agreed upon in 1986. In a related area, the major development phase of the **Advanced Servomanipulator (ASM)** was completed with the full operation of the prototype as part of the Advanced Integrated Maintenance System. Efforts to transfer the ASM technology to industry were begun and have met with much interest from the commercial sector.

Significant reductions have been made in the volumes of **low-level liquid waste (LLLW)** generated at ORNL. The volumes generated in 1986 were roughly 50% of the average 1984 levels. A major factor in this reduction was the improvement in liquid waste handling at the Process Waste Treatment Plant (PWTP).

The Consolidated Edison Uranium Solidification Program (CEUSP) facility completed **radiochemical processing** on June 3, 1986, two months ahead of the milestone date. The process operated smoothly, with downtime only for planned pump replacement. The 1050 kg of highly radioactive uranium was packaged into 401 stainless steel cans as a solid metal oxide and placed into storage.

Following the Chernobyl accident in April 1986, ORNL staff provided expertise to DOE and NRC to understand and **assess the implications of the events at Chernobyl**. ORNL staff members wrote or reviewed parts of the Factual Report prepared as a briefing book for the U.S. delegation to the late-August International Atomic Energy Agency (IAEA) meeting in Vienna. DOE funded an effort at ORNL to assemble a team including Pacific Northwest, Brookhaven, and Argonne laboratories to analyze reactor dynamic systems. ORNL staff members drafted a position statement for Secretary Herrington on international collaboration on advanced reactors in preparation for the IAEA meetings on Chernobyl. In addition, ORNL participated in the Office of Health and Environmental Research (OHER) Task Group on Health and Environmental Aspects of the Soviet Nuclear Accident and chaired the Committee on Research on the Validation of Prediction Models.

ORNL has initiated the **Advanced Control Test Operation (ACTO)**

Program, which will provide technology to model nuclear large-plant operation for developing and testing advanced control systems. ACTO's major objective is to maximize the benefits the nuclear industry can derive from advanced control technology, including advanced sensors, multiplexed fiber-optic communications, distributed computers, expert systems, and systems design of man-machine interactions.

Several important accomplishments have taken place as part of the **SDI optics program** at Oak Ridge. These include the development of rapid fabrication techniques for beryllium mirror production, in situ measurement of burst reactor radiation effects on the transmittance of infrared window materials, and the establishment of an optics characterization facility to perform state-of-the-art measurements on SDI optical components.

ORNL led the development of a Draft Programmatic Environmental Impact Statement for the U.S. Army on disposal of its **chemical weapons stockpile**. This document received praise from the Army during the public hearings on the issue.

A Final Environmental Impact Statement was prepared for seven **hydroelectric projects** in the Owens River basin. The statement addressed the cumulative effects of the projects on various environmental and social resources using a methodology developed by the Laboratory that allows the quantification of impacts on a wide range of resources on a common basis. The value of the resources was based in part on input from the public at structured meetings. The assessment methodology coupled with public involvement as such plows new ground in preparing environmental impact statements.

Martin Marietta Energy Systems, Inc., has successfully negotiated with ARCO Chemical Company the first license of its patent on the **ceramic composites toughened with SiC whiskers** that were developed at ORNL. This nonexclusive license is for use of an Al_2O_3 matrix composite for cutting tools. Field tests have shown this material to have ten times the productivity of tungsten carbide in machining nickel-base superalloys. Incorporation of the small SiC whiskers, synthesized from rice hulls by ARCO, into the Al_2O_3 results in a doubling of its fracture toughness and strength at temperatures as high as 1000°C and thereby produces a material having much greater resistance to fracture, thermal shock, and wear. This is the first of several expected licenses with manufacturers of cutting tools, wear parts, and engine components.

DOE will file for a patent on new **heat-actuated absorption heat pump concepts** developed at ORNL. The new concepts would be particularly effective in cooling and would be twice as efficient as the best existing absorption chillers. Heating efficiency increases of about 40% appear possible.

Six 40-ton **superconducting magnets** have been simultaneously energized to a magnetic field of 8 tesla. These six coils, three U.S. and three foreign [Japan, Switzerland, and Germany (for Euratom)], are being tested as part of an international effort to develop the large magnets which will be required for a power-producing fusion device. This demonstration and results of detailed engineering tests have substantially advanced the art of building large superconducting magnets and have resulted in a number of "firsts." Among these firsts are operation of the world's largest Nb_3Sn magnet and operation of the world's largest magnets cooled by the forced flow of supercritical helium gas.

ORNL pellet injectors, which produce 1-4-mm-diam solid hydrogen pellets with velocities of 1-2 km/s, have proven to be an effective means for refueling magnetic fusion devices and at the same time improving plasma confinement. A repeating pneumatic injector (RPI) was successfully used on the Tokamak Fusion Test Reactor (TFTR) at the Princeton Plasma Physics Laboratory (PPPL) for initial experiments on optimizing plasma performance. This early device has now been replaced by an improved design, the eight-shot Deuterium Pellet Injector (DPI), which was delivered to PPPL on cost and five weeks ahead of the milestone. The DPI allows arbitrary timing for the injection of each pellet in contrast to the fixed rate for the RPI and, depending on the choice of "barrel" sizes, a choice of pellet mass.

Solubilization of low-ranked coals requiring several days was previously demonstrated for various fungi with

Michael Emery and Barbara Hoffheins (Instrumentation and Controls Division) and Robert Lauf (Metals and Ceramics Division) received an I-R 100 Award for an integrated gas analysis and sensing chip.

Marcus Wise and Michelle Buchanan (Analytical Chemistry Division) received an I-R 100 Award for a multimode ionization detector.

surface cultures. Recently, ORNL demonstrated the solubilization of coals in submerged cultures by bacteria, which requires about half the processing time required for the fungi solubilization, making the process more amenable to scale-up.

DOE has approved a preliminary conceptual design for a Compact Ignition Tokamak (CIT), which is to be proposed as the next major fusion experiment to be built in the United States. The CIT is intended to study the physics of burning plasmas, the last "frontier" of fusion plasma physics before the construction of an engineering demonstration. This system will be proposed for an FY 1988 start at PPPL. ORNL made major contributions to the conceptual design, with the Fusion Engineering Design Center (FEDC) being responsible for systems engineering, design integration,

configuration development, and costing, as well as the design of the machine structure, some plasma heating, and remote maintenance systems. ORNL staff have also made significant contributions to the plasma physics effort.

Awards for Personal Achievement

- S. I. Auerbach (Environmental Sciences Division) was appointed to the Executive Committee of the EPA Science Advisory Board.
- L. W. Barnhouse and B. T. Walton (Environmental Sciences Division) were invited to serve on the National Research Council's Committee on Pyrethroids and Ecological Risk Assessment.
- K. W. Boling (Metals and Ceramics Division) was presented the Leonardo da Vinci Award by the Design Engineering Division of ASME.
- C. A. Burtis (Chemical Technology Division) received the American Association for Clinical Chemistry's National Lectureship Award recognizing his impact in chemistry.
- T. A. Callcott and E. T. Arakawa (Health and Safety Research Division) received an I-R 100 Award for a soft X-ray emission spectrometer.
- R. S. Carlsmith was elected to the Board of Directors of the American Council for an Energy-Efficient Economy.
- S. J. Dale (Energy Division) was appointed as one of the two Institute of Electrical and Electronics Engineers Congressional Fellows.
- J. W. Elwood and D. C. West (Environmental Sciences Division) were appointed to the Advisory Panel for the National Science Foundation's Ecosystem Studies Program and Ecology Program, respectively.
- M. S. Emery and B. S. Hoffheins (Instrumentation and Controls

David Ederer (National Bureau of Standards), Ken Tsang (UTK), and Tom Callcott (Health and Safety Research Division) demonstrate their soft X-ray emission spectrometer, an I-R 100 Award winner. Not pictured is E. T. Arakawa.

Division) and R. J. Lauf (Metals and Ceramics Division) received an I-R 100 Award for an integrated gas analysis and sensing chip.

- W. M. Generoso (Biology Division) was appointed to serve on the National Research Council Commission on Life Sciences' Panel on Reproductive and Developmental Toxicology of the Committee on Biological Markers.
- H. W. Godbee (Chemical Technology Division) won the American Society of Mechanical Engineers (ASME) Sarge Ozker Award.
- D. L. Greene (Energy Division) was named Chairman of the National Research Council's Transportation Research Board Committee for Energy

Conservation and Transportation Demand.

- E. L. Hillsman and F. C. Kornegay (Energy Division) and P. R. Coleman (Computing and Telecommunications Division) received an Applied Geography Project citation award from the Association of American Geographers for work in developing a Population at Risk Analysis.
- A. W. Hsie (Health and Safety Research Division) was named a Distinguished Visiting Scientist by EPA's Office of Research and Development.
- B. A. Lewis (Chemical Technology Division) received the Biophysical Society's Dayhoff Memorial Award in Biophysics.
- S. E. Lindberg (Environmental Sciences Division) received the Alexander von Humboldt Foundation Research Fellowship in recognition of scientific achievement (sponsored by the Federal Republic of Germany).
- A. P. Malinauskas (Director NRC Programs) received the DOE Ernest O. Lawrence Award and was cited for his work in nuclear technology.
- F. W. Manning (retired from Instrumentation and Controls Division) received the Federal Emergency Management Agency (FEMA) Outstanding Public Service Award for 25 years of contributions and innovations.
- J. A. Martin (Physics Division) was elected president of the Institute of Electrical and Electronics Engineers (IEEE) Nuclear and Plasma Sciences Society.
- L. B. Russell (Biology Division) was elected to the National Academy of Sciences.
- C. D. Scott (Chemical Technology Division) was elected to the National Academy of Engineering.
- C. C. Travis (Health and Safety Research Division) was appointed to the Food and Drug Administration (FDA) Science Advisory Board.

- J. E. Turner (Health and Safety Research Division) was named a Fellow in the Health Physics Society.
- T. J. Wilbanks (Energy Division) was selected for the Association of American Geographers' highest Honors Award.
- M. B. Wise and M. V. Buchanan (Analytical Chemistry Division) received an I-R 100 Award for a multinode ionization detector.

Laboratory Achievements

Technology Transfer Program.

The goals of the Office of Technology Applications (OTA) are to assist state and local governments in their use of technology and to transfer developed technology to private industry. Activities of this office reflect these goals and include the following achievements.

ORNL has signed licensing agreements with six companies:

- Ontario Hydro, Ltd., of Canada, for its use of ORNL's tritium shipping container design
- Cummins Engine Company, for the use of nickel aluminides in diesel engine technology
- Environmental Systems Corporation, for a fiber-optic luminoscope
- Instron Corporation, for a "self-aligning grip assembly," a gripping device for measuring the tensile strength of advanced ceramics
- Anflow, Inc., for anaerobic sewage treatment
- ARCO Chemical Company, for whisker-reinforced ceramic cutting tools and for wear parts

In addition to these licensing agreements, 13 nonpatented technologies were transferred to the private sector in the past year. ORNL also developed a formal licensing policy and prepared specimen agreements for exclusive copyrights, nonexclusive patents, and nonexclusive software to streamline the transfer process.

The Tennessee Center for Research and Development was formed and was awarded an Electric Power Research Institute (EPRI) contract to establish a Power Electronics Applications R&D Center.

The ORNL Robotics and Automation Council was formed to identify opportunities for collaborative research with industry and universities and facilitate technology transfer to the commercial sector.

The Laboratory sponsored nine conferences and workshops related to technology transfer, and four spin-off companies were formed during FY 1986.

ORNL received two Federal Laboratory Consortium Awards for excellence in technology transfer. A total of \$150,000 in royalties received by Energy Systems from licensing was reinvested in the Technology Transfer Program.

Ken Liu, Metals and Ceramics Division, aligns "Supergrip," a device for testing ceramic material tension. This device that provides accurate data not previously obtainable to researchers in the rapidly growing ceramics industry was licensed to Instron Corporation for commercial sales.

Current Research and Development Programs

Nuclear and Engineering Technologies

Civilian Reactor Development Program

The goal of the U.S. Civilian Reactor Development Program is to ensure that the nation's energy future is established through attractive and commercially viable nuclear energy options and the necessary technology base. The program has been restructured to more broadly address advanced converter reactor systems based on water, gas, and sodium coolants. Although the sodium-cooled breeder reactor is recognized as vital over the long term to provide an essentially inexhaustible energy supply, current predictions of uranium use have reduced the pressure for early breeder development. The liquid metal reactor (LMR) concept, however, continues to show promise as an advanced converter. Also, the high-temperature gas-cooled reactor (HTGR) shows promise as a versatile energy source for a broad spectrum of applications, including high-temperature process heat.

ORNL will continue to support DOE's concept development and base technology programs and offer its broad expertise in fission reactor and fuel recycle technology for the restructured program.

Reactor Program

Improved light-water reactor (LWR) technology is urgently needed in the United States to support improvements in performance and availability of current-generation LWRs as well as advanced concepts. Planning for and implementing this effort is based on close cooperation with EPRI, the utility industry, and the nuclear power industry. Although the major portion of this effort will be carried out by industry, the Laboratory expects to play a prominent role in DOE's expanded LWR program because of its broad expertise in LWR technology. Continuing LWR tasks include annually updating the energy economic data base and comparing economics based on engineering of nuclear options with other energy sources. New activities are emerging in support of the Electric Power Research Institute (EPRI) advanced LWR plant requirements documents, advanced LWR control systems in cooperation with industry, and special studies, such as modeling and analysis related to the Chernobyl accident.

Primary emphasis in the national HTGR Program is on development of a modular high-temperature gas-cooled reactor (MHTGR) using steel pressure vessels for the reactor core and steam generators in a side-by-side

arrangement. The use of steel vessels facilitates factory fabrication and shipment to the reactor site. The passive safety features of the MHTGR also lead to cost savings because of the potential for high-quality automated factory fabrication, streamlined licensing, standardized construction, non-safety-grade balance-of-plant construction, use of incremental financing, and fewer rate changes. In the longer term, MHTGRs show promise of broadening the applications of nuclear power to high-temperature process heat areas and to energy generation in water-limited regions.

The mission of ORNL in this activity is to provide technological expertise in support of the national HTGR Program to develop passively safe, economically attractive HTGRs for electricity production, cogeneration, high-temperature process heat, and high-temperature energy conversion. ORNL also leads the Base Technology Development Program. Technical activities include (1) performing qualification tests of HTGR fuel performance and fission product behavior under postulated accident conditions; (2) providing basic data on the mechanical, physical, and chemical behavior of HTGR materials, including metals and graphite; (3) providing analytical evaluation of shielding designs; and

(4) providing technical and economic evaluations and assessments. In addition, ORNL provides technical support to DOE by reviewing and evaluating advanced concept design documents and by participating in peer reviews of the advanced concept designs.

Future advanced LMR converter technology support will focus principally in the base-technology areas of measurement and control, shielding, materials, structural design, and safety. Emphasis is on tasks in support of (1) innovative, low-cost, and passively safe designs and (2) international collaborative efforts.

The **Advanced Control Test Operation (ACTO)**, a new activity

initiated in FY 1986, will establish a facility for development and testing of advanced control and information-handling technology, involving broad participation from both universities and industry.

Consolidated Fuel Reprocessing Program

The Consolidated Fuel Reprocessing Program (CFRP) plays an important role in the future of nuclear power in the United States, and ORNL has contributed to this effort by developing improved concepts and techniques that are recognized worldwide. Many similar

improvements are being incorporated in foreign reprocessing facilities. ORNL leads the world in efforts to develop improved methods for remote maintenance in reprocessing facilities. This innovative remote technology could be applied to a variety of activities in other hazardous environments: fusion, waste disposal, decommissioning, and cleanup of reactors and other nuclear facilities.

ORNL will continue its active role in efforts to foster international technical exchanges and other collaboration. Limited activities under the United Kingdom exchange program continue. Early in FY 1986 an agreement in remote technology was signed with France, and a similar agreement is under consideration with the Federal Republic of Germany. Exchange agreements with Japan are in place, and collaborative work is in progress in experimental criticality work and in application of remote technology. Japan's Power Reactor and Nuclear Fuel Development Corporation (PNC) is providing funding for the criticality program.

In addition, a broad collaboration with PNC is being developed as a long-term program mission. This program focus is aimed initially at a multimillion dollar per year collaborative R&D program spanning the next five to six years.

An operational prototype of the advanced servomanipulator (ASM) has been developed, and efforts to transfer this technology to industry are being pursued. Cost sharing for further development of the ASM and fees for an exclusive licensing arrangement will be negotiated with a private-sector business.

The use of centrifugal contactors for solvent extraction process applications offers the advantages of rapid startup, short solution residence time, compact size, high mass transfer efficiency, and potentially lower overall system cost when compared with more conventional contactors. Additional performance and

A Chemical Technology engineer is performing leach tests on cement grout samples. These tests help to evaluate grout formulations used in the waste isolation and stabilization studies.

reliability improvements are being achieved, and potential simplification of the overall solvent extraction system will be explored. For example, efficient centrifugal contactors may allow systems that have fewer purification cycles. Contactor applications in the nuclear industry include both commercial and defense fuel reprocessing, scrap recovery operations for fuel fabrication and weapons production, and waste processing. Testing and demonstrations of these techniques with small-scale contactor banks will use support systems within the Integrated Equipment Test (IET).

The CFRP 9-kW remote laser cutting system can be applied to the development of remote cutting, welding, and special heat-treating procedures that have wide applications. The demonstrated capability to remotely control and automatically drive the high-power laser focus head has the potential for large industrial applications requiring a high-power laser.

Space Reactor

Improved materials for space missions and terrestrial applications that use heat generated by isotopic power devices are being developed and evaluated. Activities include the production of iridium-alloy-cladding blanks to contain heat-generating radioisotopes and carbon-bonded carbon fiber (CBCF) insulators to achieve 1300°C operating temperature. In anticipation of resumed production as early as FY 1987, ORNL is maintaining its production capability and inventory of iridium.

In the interim, technology improvements being pursued include (1) development of a process to produce CBCF from a new starting product, (2) development of a consumable arc-melting technique and determination of processing ranges for the iridium alloy, and

A fluidized-bed bioreactor system is tested during Chemical Technology process development studies for biodenitrification of wastewaters.

(3) nondestructive examination support for manufacture of advanced thermoelectric elements and the iridium alloy blanks.

ORNL will continue to lead the development and characterization of high-temperature materials for the **Strategic Defense Initiative (SDI) Program** on fission reactor concepts

for power levels in the hundreds of kilowatts (SP-100 Project) as well as for the multimewatt range. In the Ground Engineering System phase of the SP-100 Project, which began in FY 1986, ORNL anticipates playing a significant role in the technology areas of reactor shielding and measurement and control.

Remedial Action Program

Major activities in Remedial Action Programs (RAPs) involve the conduct of radiological surveys on private properties near inactive mill tailings sites and at facilities formerly used under contract with the Atomic Energy Commission (AEC). State-of-the-art equipment and methodologies developed at ORNL help identify, evaluate, and document the current radiological status of sites involved in the DOE RAPs and thus help reduce health impacts caused by fuel cycle activities. To perform its activities in a cost-effective manner, the Uranium Mill Tailings RAP maintains an office staffed by the Health and Safety Research Division (HASRD) in Grand Junction, Colorado.

Nuclear Waste Management

ORNL's work for the DOE Office of Civilian Radioactive Waste Management (OCRWM) is funded by revenues from a 1.0 mil/kWh(e) tax on electricity generated by nuclear reactors plus equivalent amounts to pay for the defense high-level waste (HLW) that will be buried in the repositories. ORNL's current nuclear waste management activities include two repositories, transportation and system integration, and program management and technical support.

One of the OCRWM repositories supports continuation of the sensitivity and uncertainty analysis task for the **salt repository project**. This task is to develop a computer-based methodology to analyze uncertainty in the results of complex computer codes. Additional work is expected for first repository projects in FY 1987 and succeeding years in a variety of R&D support roles; the nature and amount of these activities depend on the budget and program directions.

The second repository supports the investigation of **sedimentary rocks**

other than salt as potential hosts for a nuclear waste repository. This program has evaluated five sedimentary rocks other than salt and prepared a draft report concluding that shale is preferred. The OCRWM is currently considering the role of shale in the second repository program. Expectations are that shale will continue to be investigated in this application on a basis that is not site specific. The **crystalline rock program** has funded ORNL transportation analyses in support of the crystalline rock recommendations issued during FY 1986. These activities are expected to be terminated because of major changes in the structure of the program. Some R&D, however, is anticipated to support the study of repository materials other than shale.

The **transportation and system integration** supports three substantial activities at ORNL. The first is the Waste Systems Data and Development Project, which develops data bases, performs technical assessments, and develops technology in areas common to multiple components of the OCRWM system. The second is to provide integration and technical support and to undertake specific technical work related to DOE-ORO's lead responsibility for the OCRWM Transportation Operations Program Office. The third involves providing analytical, experimental, and testing support to the cask development program and the institutional and economic aspects of transportation.

The program management and technical support of OCRWM supports a major portion of the Integrated Data Base project and the review and evaluation of the environmental aspects of key OCRWM documents.

Waste Management Operations

The Waste Management Operations Program includes five tasks: (1) LLW Management

Operations (solid, liquid, gaseous), (2) Remedial Action, (3) Transuranic (TRU) Waste Certification and Volume Reduction, (4) Interim Waste Management Facilities, and (5) Program Planning and Management.

The overall **solid waste** disposal strategy combines improved operations in existing facilities, volume reduction, interim storage, and demonstration of waste treatment and disposal techniques for a new disposal facility expected to be operational by the mid-1990s. A pilot-scale test using grout formation technology to produce a solid monolith demonstrated the safety and effectiveness of this process.

There are four TRU waste streams at ORNL. They are newly generated (NG), contact-handled (CH) TRU wastes; stored, CH TRU waste; NG, remotely handled (RH) TRU waste; and stored RH TRU waste. The NG-CH TRU waste stream received approval for certification in June 1986. Planning for the certification of each of the other streams is nearing completion. **Certification** requires a set process by which waste is packaged for shipment so that the acceptance criteria established for the Waste Isolation Pilot Plant (WIPP) facility are met. A facility is planned for construction beginning in the mid-1990s to repackage the contents of the concrete casks and to solidify the sludge for shipment to WIPP.

Many of the disposal units for radioactive waste used at ORNL since the early 1940s do not meet current standards for retention of radionuclides. Remedial action is therefore required to bring these units up to current standards so they can be closed. This effort will require characterization of the disposal units and their current performance, assignment of priorities, assessment of closure techniques, selection of appropriate closure action for each unit, and implementation of that action. Postclosure monitoring and

modeling will also be included in the remedial action.

Materials Production Program

The Materials Production Program includes the ^{233}U Storage and Distribution Program and the Californium Industrial Sales/Loans Program. Facilities for purification of ^{233}U , located in the Radiochemical Processing Plant (RPP) at ORNL, are being placed in standby and will be totally inactive by FY 1989; however, safeguarded storage of ^{233}U in the RPP will be continued. A conceptual design is available for installing new ^{233}U processing facilities with significantly improved capabilities should DOE's needs for ^{233}U be resumed. The new facilities would be located in two of the shielded cells at the Thorium-Uranium Recycle Facility (TURF).

The special project of converting 1000 kg of uranium (composed mainly of the fissile isotopes of uranium) from a liquid to an inert solid has been completed successfully. During FY 1987, the equipment and storage tank for this project will be flushed and put in standby.

Facilities for the Californium Industrial Sales/Loans Program were installed in other shielded cells at TURF in FY 1986, and operations are scheduled to begin in early FY 1987. The purpose of this program is to fabricate ^{252}Cf into neutron sources or into bulk packages for sale to industry or for loan to other government agencies.

Hazardous Waste Program

The Hazardous Waste Program Support Contractor Office (SCO) supports the ORO Hazardous Waste Program in the technology aspects of hazardous and mixed waste (HMW) management at all DOE Defense Program (DP) facilities. The SCO assists DP facilities with the technologies required for sound management of HMW, including

reduction, transportation, treatment, storage, and disposal of wastes and environmental restoration. The SCO identifies and evaluates DP facilities waste management problems and issues, supports technology development and technology transfer to handle waste management problems, develops waste management strategies, and assists DOE Headquarters staff in HMW policy development.

The SCO developed and maintains the Waste Information Network, a computer-based communications

system that allows DP contractors, Operations Offices, DOE Headquarters, and the SCO to exchange information quickly and efficiently. The SCO analyzes both proposed and new legislation and regulations affecting DP waste management and distributes manuals, analyses, and regulatory alerts to the DP waste management community. The SCO will continue to support ORO and DOE Headquarters as waste management needs become better defined and means for dealing with HMW evolve.

The ORNL high-temperature thermal shock tests are carried out in a specially designed 30-kW induction heating facility that can repeatedly impose a prescribed thermal cycle.

As a result of past operations and changing environmental legislation and standards, ORNL is undertaking major hazardous waste R&D to effect major operational and environmental improvements. Significant work is anticipated in a site cleanup demonstration, using actual contaminated sites on DOE property to develop and demonstrate advanced technologies, including in situ stabilization technologies, compaction, monitoring and verification technologies, groundwater diversion, risk assessment, and transportation route logistics—all of which are areas of ORNL prominence. Experience in addressing these problems is in high demand by DOE and other federal agencies.

Because of the aggressive manner in which ORNL has begun addressing existing problems with hazardous and radioactive waste and the broad base of experience ORNL has brought to bear on these problems, other federal agencies (including all branches of the DOD, EPA, and DOT) are requesting technical assistance in the areas of hazardous and radioactive waste management and technology development.

Remedial action planning involves detailed technical evaluation of potential hazards of existing sites contaminated by hazardous waste, evaluation of potential remedial action alternatives, selection of a preferred alternative, and development of a conceptual design for the selected remedial action.

This activity requires a multidisciplinary technical approach involving environmental sciences, engineering, economic analysis, and design disciplines. Energy Systems has been given responsibility for the U.S. Air Force Remedial Action Planning Program and will manage such analyses and develop necessary methodologies. Remedial action planning work and related R&D are prime areas for future work with

EPA, the U.S. Army, and the U.S. Navy.

Hazardous waste technology development is currently provided to the U.S. Air Force Engineering and Services Center, Strategic Air Command, Tactical Air Command, Logistics Command, Systems

Command, Military Airlift Command, Air Training Command, Naval Energy and Environmental Support Activities, and Naval Facilities Engineering Command. Projects include development of (1) designs for live-fire training facilities that comply with hazardous waste

A new technique has been developed at ORNL to use small (1-mm-diam) gel beads that act as catalysts in a continuous fluidized-bed system for producing fuel alcohol from corn sugars.

control regulations, (2) state-of-the-art vapor control technologies for jet fuel storage, (3) munitions that are less hazardous during storage and transportation, (4) hazardous materials tracking and emergency response expertise, and (5) robotics for hazardous materials handling. Technology is the major area of growth seen for WFO in hazardous waste management.

ORNL has recently established a **Hazardous Waste Technology Program** to undertake R&D activities concerning hazardous and mixed wastes. A major source of funding for these efforts will probably be DOD in support of these efforts to clean up various waste legacies and to bring waste management practices into compliance with current regulations. Activities may include process

development, technical assessments, technical support, and planning and integration support, with funding coming from all branches of the military.

Waste Management Technology Center

Energy Systems and DOE-ORO have established a Waste Management Technology Center (WMTC), which serves as the technology component of a comprehensive DOE-ORO waste management coordination effort referred to as the "Oak Ridge Model." The WMTC centralizes special functions formerly carried out in various waste management organizations in the ORO-managed complex. The charter of the WMTC

encompasses treatment, storage, and disposal technologies relevant to the management of transuranic, low-level, hazardous, and mixed wastes. The WMTC also provides technical support for the development and analysis of technical information supporting remedial actions and compliance strategies by DOE-ORO contractors, including Energy Systems. The expertise available in several of the R&D divisions at ORNL will be used in planning and evaluating technology demonstrations and evaluating the associated implications for the protection of human health and the environment and compliance with regulations. These planning and evaluation exercises will be supplemented by a series of technical workshops that will be conducted by WMTC to assist in evaluating issues and in assessing potentially useful technologies within a broad context.

The WMTC will emphasize a technology demonstration program based on cost sharing, which ensures that the expertise of the private sector is efficiently employed while providing answers to current waste management problems on DOE-ORO sites. The facilities managed by DOE-ORO will be used as a laboratory for the demonstration of waste management technologies using actual DOE wastes. Demonstrations will be conducted on scales large enough to provide credible assessments of cost and performance for full-scale systems and will be adequate to determine regulatory compliance. This technology demonstration program will provide centralized coordination and quality assurance for the procurement, siting, permitting, and performance evaluation aspects of technology demonstration projects and will include active participation by state and federal regulatory agencies in all aspects of the program.

The WMTC will encourage technology development and

The components of the Oak Ridge Model include technology research, development, and demonstration; regulatory interface; public information; and technical interface/technology transfer. The focal point is the Waste Management Technology Center.

application by providing a low-risk demonstration environment through both the partial identification of subcontractors and the protection of patent rights associated with demonstrations on DOE-ORO sites. Special efforts will be made to work with universities that the state of Tennessee has designated as Centers of Excellence in environmental and waste management areas.

Strategic Defense Initiative Office

The Oak Ridge complex has extensive experience in many

technology areas closely related to the mission requirements being considered in the DOD SDI. Specifically, this program will use the Laboratory's expertise in compact, lightweight power and energy storage systems, neutral particle beam systems, optical components, and shield structures.

Oak Ridge facilities will participate in efforts to develop and evaluate **power and energy storage systems**, resulting in a technology development program. In cooperation with other DOE and DOD laboratories and with private industry, the Oak Ridge complex will implement these technologies in

systems to meet SDI requirements. Previous work in neutral particle beam research at Oak Ridge has resulted in the development of negative particle sources having high particle production and low beam divergence, which will be used to help provide the high-intensity, tightly collimated beam needed for directed energy applications. Oak Ridge expertise in mirror fabrication technology, ion implantation, and radiation testing will support DOD in developing radiation-hardened, passive optical components. Experience in developing shields against natural radiation in space, high-kinetic-energy projectiles, and neutron and gamma fields will be applied to develop shields to increase the survivability of SDI space assets.

Some examples of technology areas to be pursued are (1) for reactors—core performance, two-phase flow, materials, shielding, and instrumentation and controls; (2) for energy storage—flywheel fabrication and testing, thermal-energy storage systems, power conditioning, and system reliability; (3) for beam systems—ion source design, fabrication and performance testing, radio frequency quadrupole design, beam neutralization, and beam steering studies; (4) for optical components—precision machining, surface smoothing through ion implantation, and studies of radiation effects on optical properties of mirrors and windows; and (5) for survivability shielding—shield design, sample manufacturing, sample testing and evaluation.

Other areas of work that will be pursued include (1) kinetic energy technology—especially high-acceleration testing of electronic components, projectile development, and materials studies; (2) surveillance technology—especially discrimination concepts; (3) scientific computing support; (4) lightweight materials development for space structures;

Large dynamic-fracture specimens of reactor-vessel-grade steel are designed and fabricated at ORNL for testing in the large tensile machine at the National Bureau of Standards in Gaithersburg.

(5) new concepts that can lead to major advance in defense system capabilities; and (6) technical information systems.

Nuclear Regulatory Commission

Through its various programs at ORNL, the Nuclear Regulatory Commission (NRC) receives research and technical support in areas in which the Laboratory has demonstrated significant expertise. These areas include structural analysis, materials evaluation, fission product behavior, accident sequence analysis, advanced instrumentation and diagnostics, reliability and operating data analysis, integrated risk assessment, and radiation dose and health effects. Based on current NRC budget projections, ORNL efforts are expected to decline as the NRC research budget decreases, resulting in unfortunate losses of expertise in several areas. ORNL activities for NRC are divided into six categories, which reflect work for the different offices funding the efforts.

For the **Nuclear Reactor Regulation Office**, ORNL provides technical consultation and specialized measurements for test methods to detect anomalous behavior in LWRs.

The Laboratory furnishes technical support for the **Office of Administration** through the Radiation Shielding Information Center and the Technical Data Management Center.

Efforts on behalf of the **Office of Nuclear Materials Safety and Safeguards** include shipping-cask analyses, environmental assessments of fuel cycle facilities, technical support and laboratory-oriented evaluation in geochemical areas related to the licensing of radioactive waste repositories, and surveys of metabolic data appropriate to high-level waste dosimetry. Continued interest in environmental assessment tasks and waste management is anticipated; however, NRC's plans to

develop a federally funded research center, independent of a national laboratory, to provide technical support to high-level waste repository licensing activities may severely impact this work in FY 1988 and beyond.

The Office of Nuclear Regulatory Research supports the largest NRC program at ORNL. Relatively large efforts are under way for obtaining an improved data base for the behavior of fission products and aerosols in severe reactor core damage accident situations and for the long-term behavior of reactor pressure vessels. The issuance of a Commission Policy Statement on severe reactor core damage accidents has resulted in a decrease in the fission product research activities. Interest in extending the operational life of existing power plants beyond their original design has increased, and this is expected to result in increased research in aging characteristics of plant components.

Over two-thirds of the funds from the **Office for Analysis and Evaluation of Operational Data (AEOD)** support the Sequence Coding and Search System (SCSS), which is performed by the Nuclear Operations Analysis Center. The SCSS task involves the development and operation of a new system for increasing the usefulness of the descriptive text contained in Licensee Event Reports. Other activities include operation and maintenance of a non-reactor-related data file and a proprietary foreign reactor events file.

The Laboratory assists other NRC offices in verification, inventory, and analysis of special nuclear materials samples, preparation of site-specific material standards, and review of environmental assessments and operation procedure changes for the regional offices. In addition, ORNL has developed and maintains a computer data base of construction deficiencies.

ORNL budget outlays and full-time equivalent personnel projections for Fission Programs are shown as a percentage of the total ORNL budget outlay and full-time equivalents.

Advanced Energy Systems

Fusion Energy

The Magnetic Fusion Program at ORNL is a major component of the national fusion program and contributes in nearly all aspects of magnetic fusion research. The goal of the national fusion program is to determine whether useful energy can be obtained from the fusion of the light elements, mainly isotopes of hydrogen and lithium. Key issues at the current stage of the program are to (1) understand the behavior of high-temperature hydrogen isotope plasmas in order to develop magnetic configurations that confine plasmas effectively and that have attractive engineering features; (2) understand the physics of burning plasmas (i.e., plasmas in which nuclear fusion is occurring); (3) develop technologies for producing, heating, and controlling such plasmas; (4) develop fusion nuclear technologies for components that operate in the fusion reactor environment; and (5) develop materials for the fusion reactor environment. Within the DOE Magnetic Fusion Program, the first two issues are primarily addressed in the Applied Plasma Physics (APP) and Confinement Systems subprograms, whereas the remainder are contained within the Development and Technology (D&T) effort.

The APP activities include theoretical studies to formulate and apply models of plasma behavior in various confinement systems; in the future, we expect the greatest emphasis to be on the tokamak and stellarator systems, while a lower level of effort may be expected on the Elmo Bumpy Torus (EBT) and reversed field pinch concepts. This activity also encompasses the development of a data base and of models for atomic physics and the development of diagnostic devices. In the tokamak and stellarator areas, work will continue to develop theory

An ultrasonic ranging and data system (USRAD) was developed by Instrumentation and Controls Division for the Health and Safety Research Division's work with the Uranium Mill Tailing Remedial Action Program. Shown are B. Berven and M. G. Yalcintas of the Health and Safety Research Division and C. H. Nowlin, M. S. Blair, and V. C. Miller of the Instrumentation and Controls Division.

(both for comparison with experiment and for predictive calculations) in the areas of magnetohydrodynamics, heat and particle transport, and heating and fueling. Studies of critical issues will be made for the Advanced Toroidal Facility (ATF), a stellarator, to be operating at ORNL in 1987, and for the Spherical Torus Experiment (STX) proposed by ORNL. Studies will continue of advanced systems for the 1990s, such as ATF-2, the Compact Ignition Tokamak (CIT) experiment proposed for the Princeton Plasma Physics Laboratory, and international engineering test reactors, such as TIBER and INTOR. In the atomic physics program, a powerful new source of multiply charged ions is operating, which considerably expands the range of highly ionized systems available for investigations. The measurement of atomic cross sections on this device, coupled with theory, will sustain a vigorous program in this area for a number of years. In a

separate program, the development of a diagnostic device for measuring fusion alpha particles will continue.

The Confinement Area has two major program elements. The first is the design, construction, and preparation for operations of the ATF stellarator. This facility will be available for the experimental program to start in FY 1987, and it is planned to operate into the early 1990s. ATF will provide a major in-house focus for theory and experimentation, diagnostics, and plasma technology. The second element is the definition of physics and engineering issues associated with a tokamak operating at a very low aspect ratio—the spherical torus concept. This device promises improvements in some plasma confinement parameters over conventional tokamaks, and it offers high leverage in the study of fundamental tokamak physics issues, important to the optimization of the tokamak reactor.

The D & T Program continues to make progress on all fronts. A Radio Frequency Test Facility (RFTF), based on the prototype EBT proof-of-principle coils, is being used for testing advanced radio frequency (rf) development components. Development of rf systems and components is proceeding, with initial applications in operation or planned on a wide range of experiments in the United States and Europe. The Pellet Injector Program is working to develop advanced pellet injectors that can repetitively provide pellets at speeds of 2 km/s and higher. Injectors are being used to fuel the Tokamak Fusion Test Reactor (TFTR), Doublet III-D tokamak (DIII-D), Princeton Large Torus (PLT), Princeton Beta Experiment, and Alcator-C experiments in the United States. Systems are being designed for Tore Supra (France) and the Joint European Torus (European Economic Community).

In the Large Coil Task, the International Fusion Superconducting Magnet Test Facility (IFSMTF) (formerly known as the Large Coil Test Facility), consisting of a six-coil torus has been tested to full field (8 tesla). Testing will continue in FY 1987, when the program will be completed.

The Plasma-Materials Interactions Program is focused on limiter development, wall conditioning/impurity control, scrape-off layer diagnostics, and surface physics. Until startup of the ATF in FY 1987, the activity is concentrating on collaborative programs on Heliotron-E (Japan), TEXTOR (Jülich, Federal Republic of Germany), and Tore Supra. In the radiation materials area, testing of candidate first-wall and blanket materials is in progress. A multiyear program is under way and will continue to pursue three primary goals: to (1) provide materials behavior information in support of reactor design studies, (2) select structural materials and develop

a data base for near-term fusion devices, and (3) develop low-activation alloys for commercial fusion reactors. The program involves strong collaboration with the Japan Atomic Energy Research Institute (JAERI). Programs involving ceramics and copper are in the planning stage.

The Fusion Engineering Design Center (FEDC), managed by ORNL in collaboration with a number of U.S. industries, national laboratories, and universities, is a major contributor to conceptual design of the CIT, which is the candidate for the next major focus of the U.S. Magnetic Fusion Program. The FEDC also plays a leading role in physics and engineering studies for the U.S. contribution to the INTOR activity. In addition, in collaboration with Lawrence Livermore National Laboratory (LLNL), a modest effort is devoted to the design of the TIBER, Engineering Tokamak

Reactor (ETR) concept. As the ETR program grows, it is hoped that ORNL's role will expand.

In the Ignition Device Program, ORNL's Fusion Energy Division is also providing leadership in coordinating plasma physics activities. Through this work, the FEDC effort, and support to other technology areas, the ignition experiment is expected to be an increasingly important part of the ORNL program in future years.

Fossil Energy

The principal activities of ORNL's Fossil Energy Program are in the areas of materials for coal conversion and utilization systems; environmental, health, and safety studies related to coal conversion technologies; and fuel supply modeling. The Fossil Energy Program also supports smaller, but nevertheless important, activities in the areas of bioprocessing of coal and advanced technologies for coal liquefaction.

ORNL budget outlays and full-time equivalent personnel projections for Fusion Energy Programs are shown as a percentage of the total ORNL budget outlay and full-time equivalents.

In the Fossil Energy Materials Program, ORNL is developing alloys for use in superheaters and reheaters in advanced steam/electric cycles based on fluidized-bed or pulverized-coal combustion. The thrust of this work over the next five years is to modify existing alloys and develop new alloys for use in these advanced systems that will meet stringent criteria for strength and corrosion resistance. The resulting alloys are expected to satisfy the needs of industry for such alloys when combustion systems employing advanced steam cycles are operational in the 1990s. A second activity involves the development of nickel-iron aluminides that may be used in steam or gas turbine applications. This work extends the highly successful development of nickel aluminides at ORNL by substituting iron for some of the nickel. The important implications for this extension are cost reductions and improved corrosion resistance in the

The final segment of the helical field coil in Fusion Energy's Advanced Toroidal Facility is installed and aligned.

The eight-shot pneumatic pellet injector (shown with S. K. Combs) was developed and tested in the Fusion Energy Division and is being used presently for plasma fueling experiments on the Tokamak Fusion Test Reactor at the Princeton Plasma Physics Laboratory. The device provides up to eight frozen deuterium pellets of variable sizes (3- to 4-mm in diameter) at speeds approaching 2 km/s.

sulfur-bearing atmospheres typical of coal conversion and utilization systems. The initial development work on these nickel-iron aluminides will be completed by the end of FY 1987. During FY 1987, however, final alloy selection will be made for the production of higher heats for use in the demonstration of the fabricability and use of these alloys in operating plants.

Fiber-reinforced ceramic composites with improved strength and toughness are being produced by a novel chemical vapor infiltration and deposition process developed at ORNL. In this process, reactant gases are passed through a ceramic fiber body and reacted to form a ceramic matrix that is bonded to the ceramic fibers. The successful completion of this work will lead to the use of these ceramic composites in a variety of fossil energy systems such as high-temperature heat exchangers,

recuperators, and hot-gas cleanup filters. Basic studies of erosion and corrosion are aimed at developing a fundamental understanding of these processes and the relationship of the properties of materials to their resistance to degradation by erosion and corrosion.

A unique device was developed at ORNL to study damage to the surfaces of materials as a result of individual particle impacts. The device consists of a scanning electron microscope with modifications to permit in situ erosion studies. Corrosion research at ORNL centers on studies of the formation and breakdown of protective oxide scales, particularly in sulfur-containing atmospheres. The goal of this work is to understand the composition and characteristics of alloys that are necessary for the formation of adherent protective oxide films and scales.

The ORNL Fossil Energy Program is actively concerned with the environmental, health, and safety (EH&S) issues surrounding various coal conversion and utilization plants. Specifically, preparation and reviews of environmental documents for projects funded by the Synthetic Fuels Corporation and the Clean Coal Technology Program are a large part of this activity. In addition, the EH&S data from various fossil energy projects are collected and archived in an on-line, computer-based EH&S Information System for future reference. We anticipate that ORNL's EH&S support will continue to grow and expand over the next five years to address the needs of second-generation fossil energy plants. ORNL's Fossil Energy Program is addressing an important concern of the synthetic fuels industry in a determination of the toxicological effects of synthetic fuel products. As a part of this effort, the Laboratory is examining additional process treatments to reduce any toxicity resulting in liquid fuels produced by

current technology. The relative use of synthetic and natural fuels is to a large extent based on their availability and market considerations throughout the world. For these reasons, the ORNL Fossil Energy Program models fuel supplies and market penetration and has developed a family of generalized equilibrium models of liquid and gaseous fuel supplies that can be used to analyze the impacts of offshore leasing policies on domestic supplies, as well as to forecast the replacement costs of domestic crude oil. The models can also be used to plan future research directions so they are compatible with current trends in technology and the marketplace and to analyze the effect of the market penetration of synthetic fuels and unconventional oil and gas technologies.

The bioprocessing of coal is being explored through the use of microorganisms to convert coal into useful liquid products. Bioreactor

concepts that maximize coal solubilization and product yields are being examined. Work in the area of direct liquefaction is oriented toward examining advanced concepts for contacting coal with solvents. Recent studies indicate that the ability of the solvent to contact all portions of the coal particles can strongly influence the yield of useful products.

Conservation and Renewable Energy

In Conservation and Renewable Energy, ORNL develops new technologies that can utilize alternative energy sources and use energy more efficiently.

The Electric Energy Systems Program develops technology for transmission and distribution of electricity. Activities include dielectric, distribution automation and control, systems research, high-voltage alternating current (HVAC),

ORNL budget outlays and full-time equivalent personnel projections for Fossil Energy Programs are shown as a percentage of the total ORNL budget outlay and full-time equivalents.

high-voltage direct current (HVDC), materials, electromagnetic pulse (EMP), and electric fields.

A significant accomplishment during FY 1986 was the installation of a major part of the equipment at the Athens Automation and Control experiment and the start of data collection. During FY 1987, the installation of hardware at Athens will be completed, and experiments and data analysis will continue. Transfer of operating experience and economic analysis to the utility industry will be emphasized.

The dielectrics research will emphasize liquid dielectrics and SF₆ spark toxicity. Research tasks will be continued in the areas of electromagnetic pulse, field effects, and power systems. Budget restrictions are expected to curtail activities in HVDC, HVAC, and materials development.

ORNL is responsible for the thermal energy storage areas of diurnal storage and industrial processes. Program objectives are to develop (1) concepts for economical heat pump thermal storage, (2) technologies for significantly increased use of high-temperature industrial reject heat, (3) concepts for passive solar heat storage, (4) a data base for new heat storage materials and processes, and (5) effective interactions with the private sector to determine research needs and to transfer developed technologies.

The principal activity in solar energy is long-term research on the production of woody and herbaceous biomass. Some specific tasks are (1) development and administration of research on woody plants subjected to intensive culturing for high productivity; (2) development and administration of research on

herbaceous crop resources; (3) research on economics of energy crops and on environmental effects, physiology, and nutrient utilization; and (4) interactions with the International Energy Agency Biomass Working Group member nations.

ORNL manages four programs in the buildings area: Building Thermal Envelope Systems and Materials (BTESM), Building Energy Retrofit Research, Building Equipment Research, and Residential Conservation Service (RCS). The BTESM Program provides technical information to insulation and building industries on the thermal performance of building envelope systems. A National Program Plan selects research projects, and in FY 1986, construction began on the building to house the Roof Research Center user facility and on the environmental chamber for the center.

In Building Energy Retrofit Research, ORNL leads technical efforts for single-family and commercial buildings. A multiyear plan for each sector includes sector characterization, analysis and monitoring of retrofit performance, improvement of retrofit selection and diagnostic tools, and development of retrofit implementation and technology transfer mechanisms.

The Building Equipment Research Program seeks to conserve energy by developing improved heating and cooling systems to make better use of space-conditioning energy in buildings. Activities include analytical studies, development of analytical tools, and laboratory and field experiments. Major program areas are vapor-compression systems, nonazeotropic refrigerant mixtures, ground-coupled heat pumps, absorption heat pumps, Stirling engine-driven systems, and internal combustion engine-driven systems. During FY 1986, advanced model absorption heat pumps achieved predicted performance.

The RCS Program supports DOE's rule-making activities,

Randall Wetherington, an engineer in the Instrumentation and Controls Division, is pictured with a high-speed data acquisition system used in the Athens Automation and Control Experiment in Athens, Tennessee. The ORNL-developed system provides support for a variety of experiments that require a minicomputer-based portable data acquisition system.

International, ORNL, and Y-12 Plant participants in the Large Coil Task pose in front of the dome of the 11-m vacuum tank of the International Fusion Superconducting Magnet Test Facility just after it was closed to begin operation. Inside is a toroidal array of six test coils from the United States, EURATOM, Japan, and Switzerland that is providing information for design of magnets for fusion reactors.

the next two years, in accord with the resource requirements identified in the program plan, *Ceramic Technology for Advanced Heat Engines*. The approach includes determining the mechanisms controlling reliability, improving processes for fabricating ceramics, and testing ceramic materials in simulated engine environments. Research is coordinated closely with complementary ceramics tasks funded by other DOE offices, National Aeronautics and Space Administration (NASA), DOD, and industry.

A new facility, the **High Temperature Materials Laboratory**, is scheduled for completion and occupancy in FY 1987. This facility will house laboratories and unique special equipment for high-temperature materials research by ORNL staff and researchers from industry, universities, and other government laboratories.

technical assistance for implementation of rules, and evaluation of selected state and utility programs.

ORNL is responsible for two projects in **Industrial Conservation**. The first of these, **Materials for Waste Heat Utilization**, provides materials technology support to DOE and its contractors in support of recuperator development. The objective of the second project, **Chemical Heat Pumps**, is to develop chemical heat pump technology for recovering industrial and process waste heat.

ORNL work in **Transportation** includes development of ceramic technology for advanced automotive heat engines, analysis of transportation data related to energy use, and technical management of the **Alternative Fuels Utilization Program**. The **Ceramics Technology Program** may increase in size during

ORNL budget outlays and full-time equivalent personnel projections for Conservation and Renewable Energy Programs are shown as a percentage of the total ORNL budget outlay and full-time equivalents.

Biomedical and Environmental Sciences

Goals of the Biomedical and Environmental Sciences Program are (1) to study the interaction of energy-related physical and chemical agents with living organisms, including their transport, chemical evolution, adverse health effects, and ultimate consequences in humans and their environment; (2) to contribute to DOE's Nuclear Medicine Program and other beneficial applications programs; and (3) to transfer research findings and technological developments outside the Laboratory.

Research areas in **biology** include mammalian genetics, molecular genetics, protein engineering, carcinogenesis, radiation biology chemical interactions and effects, and information science. **Environmental science** research covers biogeochemistry, hydrology, environmental toxicology, global ecology, environmental risk analysis, geology, carbon dioxide (CO₂), and acidic deposition. **Health and safety research** encompasses epidemiology, health assessments, radiation and chemical physics, dosimetry, nuclear medicine, and instrumentation development for sensitive detection and monitoring of chemicals.

In addition, three unique **user facilities** are supported by the Biomedical and Environmental Sciences Program: the Health Physics Research Reactor (HPRR), the Oak Ridge National Environmental Research Park (NERP), and the Bioprocessing Research Facility User Resource. The NERP Program coordinates all environmental research activities with other land uses and serves as the repository of data on long-term reservation research. The bioprocessing facility integrates physical resources from the Biology and Chemical Technology divisions to include bioreactors, a flow cytometry laboratory, large-volume fermenters, and centrifugal analyzers.

Scientists Liane Russell and Clyde Montgomery of ORNL's Biology Division examine mice to learn the extent to which radiation and chemical substances cause inherited birth defects.

Basic Biological and Biomedical Research

Emphasis on **mammalian genetics** research is increasing in the Biology Division to provide information on the human genome, either directly utilizing human cellular systems or by extrapolation from animal models. Molecular characterization of DNA damage and repair and the analysis of mutations and chromosome alterations allow an understanding of the mechanisms of induction of mutational events.

Areas of emphasis in **molecular genetics** include genomic structure, regulation of gene expression, and structure and function of gene products. **Protein engineering** (site-directed mutagenesis), a new initiative

in FY 1985, is unique among DOE laboratories. Protein engineering integrates many activities in molecular genetics. The ability to insert specific mutations into cloned genes will permit the systematic design of new gene products as mechanistic probes of protein function and the tailoring of operons to alter the regulation of gene expression.

ORNL **studies of cancer** combine investigations of mechanisms and of the practical problem of risk estimates, especially for high linear energy transfer (LET) radiation. Molecular genetic techniques will be used to define the mechanisms of the hormonal regulation of gene expression and of the action of regulatory genes involved in differentiation. Studies will define the

role of transposable genes in the development of malignancy and of the genes that control the neoplastic expression of the oncogenes.

Radiation will be used to determine the role of specific molecular and chromosome alterations in the induction of leukemia. Studies at different levels of biological organization will be carried out to characterize the relationships of radiation quality and cancer induction and susceptibility and genetic background.

Information science activities include the development of data bases for EPA. The environmental mutagens, teratogens, and carcinogens data bases are part of EPA's **Gene-Tox Program**. The objective of the Gene-Tox Program is to conduct a systematic review and analysis of the genetic toxicology literature and to establish a registry of test results for chemicals evaluated in selected short-term bioassays. To date, the program has accumulated a peer-reviewed registry of test results on 420+ chemicals (1580 added during FY 1986). The Gene-Tox Program aids the EPA in establishing standard

genetic testing and evaluation procedures for the regulation of toxic substances.

Regional and Global Environmental Concerns

Environmental research is designed to increase our understanding of the transport and effects of **energy-related contaminants** in the environment. Basic information is developed on mechanisms that govern ecosystem function, particularly in biogeochemical cycling studies on forested landscapes and streams. This forms the basis for research on the ecological response to chemical emissions stressing both aquatic and terrestrial environments. By using process studies with stable elements, radionuclides, and trace organics as well as mathematical simulation models, data and methodologies are developed that improve our ability to site and operate energy systems in a cost-effective and environmentally safe manner. Work in **hydrology** and **geochemistry** supports DOE programs in subsurface transport of hazardous substances.

*Rhonda K. Jones, a summer student from Fort Valley State College, collects data for population monitoring on the rare plant *Delphinium exaltatum*. Jones is a participant in the Special Summer Program at ORNL sponsored by the DOE-University-Laboratory Cooperative Program that offers summer employment for talented undergraduates attending Historically Black Colleges and Universities.*

Howard Adler and Weldon Crow (Biology Division) prepare a fermentation tank to grow large quantities of microorganisms for biochemical research. The 500-L fermenter is part of the Bioprocessing Research Facility User Resource.

In the area of **global environmental concerns**, ORNL is a center of expertise in the investigation of ecological transport and effects of chemicals in the environment and in the assessment of hazardous wastes, the global carbon cycle related to CO₂-induced climate change, and acid deposition issues. Research on vegetation response to air pollution stress (particularly O₃, SO_x, NO_x, and acid deposition) has achieved national prominence. Research efforts are expanding to encompass the role of terrestrial-aquatic links in the processing of atmospheric pollutants. As with most technology-related pollution problems, an

interdisciplinary approach is required for planning and conducting the appropriate research. Environmental Sciences Division (ESD) research focuses on biogeochemical cycling at the watershed scale including atmospheric deposition inputs, subsurface hydrologic transport, and element cycles and effects in streams and river/reservoir ecosystems. ORNL serves as an important research and modeling center for the Office of Energy Research (OER) in the fossil fuel emissions of CO₂ and global carbon cycle and provides

support for the DOE Carbon Dioxide Research Division.

The Carbon Dioxide Information Center (CDIC) supports the nation's carbon dioxide research program and cooperates in information exchange with the international scientific community addressing global atmospheric CO₂ problems. CDIC's objective is to provide a focal point for compiling and distributing CO₂-related information under systematic quality control. The center's main function is to serve the information needs of researchers

evaluating the effects of increased CO₂ on the global carbon cycle, climate, and vegetative response and the indirect effects of elevated CO₂ levels. CDIC staff participates in R&D activities in addition to information dissemination.

Health and Environmental Risk Assessment

Research in the Health and Safety Research Division (HASRD) is directed toward improving knowledge of the detection and bioeffects of energy-related chemical and physical agents, particularly in terms of the overall impact on human health. The broad scope of the division's activities deals with detrimental effects of energy production on human beings and their environment; development of measurement capabilities that meet current and future needs for assessing exposures of people to various insults; and development of assessment methodologies that allow quantitative judgments to be made on current and future impacts of various energy strategies, energy production levels, and possible energy-related mishaps.

Development of techniques that provide advanced instrumentation for characterizing and sensitively detecting a wide variety of chemical species is emphasized. Included in this effort are unique applications of laser optical techniques, ultraviolet and soft X-ray spectroscopic techniques, electron beam microlithography, and electron microscopy. New instruments and measurement techniques that help evaluate the potential health and environmental impact of new energy technologies continue to be developed. Results of this research have led to the development of cost-effective luminescence techniques for rapid screening of samples containing polynuclear aromatic compounds as well as portable instrumentation for on-site use at operating facilities. Coupled with the emphasis on instrumentation for occupational

Bruce Warmack of the Health and Safety Research Division uses ORNL's ultra high vacuum scanning-tunneling microscope to examine atomically clean surfaces.

monitoring is the investigation for biological indicators of exposure to chemical pollutants and subsequent physiological response. Research has recently been initiated to determine which biological screening systems may be more predictive of human-level health effects. This research directly supports new health effects assessment methods.

The Nuclear Medicine Program has received widespread recognition for the design, synthesis, and animal testing of new radiolabeled compounds for use in clinical nuclear medicine and other fundamental biomedical research. A major effort of this program is the development of new, improved radiolabeling techniques and the design of new tissue-specific agents for the evaluation of tissue anatomy, perfusion, and metabolism. The Nuclear Medicine Program is complemented by an active extramural collaborative effort through cooperative programs with medical institutions such as Massachusetts General Hospital and the Boston Children's Hospital. The program is increasing interaction with Oak Ridge Associated Universities (ORAU) and the departments of Nuclear Medicine and Radiology at The University of Tennessee at Knoxville (UTK) to establish a Regional Center of Excellence in Nuclear Medicine Research.

Indoor air quality and water quality as related to human health are receiving increased attention at the national level. Recent public interest in the federal agency attention to indoor air quality has focused on radon in homes. ORNL plays an important role in developing a better understanding of radon source identification, transport assessment, mitigation effectiveness, and health effects. Radon research is only one component of a broader, multiagency-sponsored Indoor Air Quality Program at ORNL. The first phase of epidemiological studies on

Intravenous administration of iridium-191 m for the evaluation of cardiac function using the $^{191}\text{Os}/^{191}\text{Ir}$ m generator developed at ORNL.

drinking water quality and human health has been completed. These studies have led to formulation of new hypotheses concerning associations between drinking water and human health.

University Programs

Through both formal programs and informal associations, interactions between the Laboratory and the university community continue to provide a two-way flow of technical information. The DOE-OER University Laboratory Cooperative Program (ULCP) supports research participation and training of students and faculty at ORNL through both ORNL and ORAU. Support from this program continues to contribute significantly to the number of students and faculty participating in ORNL research, even though the majority receive financial support from the Laboratory's divisions and other sources (such as colleges and universities, fellowships, and grants). Over 1600 guests (more than 950

university based) participated in ORNL's FY 1986 activities. Opportunities are provided for associate degree candidates, undergraduate students, graduate students, postgraduates, and faculty to engage in research and receive advanced training for assignments as long as two years. ORNL also hosts high school teachers during the summer and high school students year round.

Many other ad hoc activities take place as part of the University Relations Program. ORNL contributes to the development of university personnel and equipment resources through staff lectures at universities, equipment purchases under subcontract, and used equipment donations. The Laboratory also provides assistance on request in reviewing proposals and developing curricula. Over 30 ORNL staff members are adjunct professors at institutions such as The University of Tennessee at Knoxville (UTK), Knoxville College, Tennessee

Technological University, and Roane State Community College.

A close relationship exists between ORNL and UTK. A number of joint activities are ongoing under the umbrella of the State of Tennessee Center of Excellence called the Science Alliance. As part of this program, nationally known scientists have received joint appointments to ORNL and UTK in the Distinguished Scientist Program. This program, established in 1984, is jointly funded by the state of Tennessee and DOE and is intended to attract outstanding scientists and engineers and to increase the interactions between UTK and ORNL. The goal of the program is to appoint up to 30 Distinguished Scientists by 1990. A number of joint graduate programs exist; some are long standing, such as the University of Tennessee–Oak Ridge Graduate School of Biomedical Sciences, located in ORNL's Biology Division, and the Graduate School of Ecology in ORNL's Environmental Sciences Division. New joint graduate programs are being developed in

fields such as measurement and control engineering and biotechnology.

A major initiative continues to be the development of the program encouraging the involvement of Historically Black Colleges and Universities (HBCU) in ORNL programs. ORNL has increased the number of participants from HBCUs involved in summer programs. In FY 1986, the Special Summer Program for undergraduates in science and engineering at HBCUs provided appointments for ten students. Additionally, in FY 1986, through programs administered by ORAU, the Laboratory hosted five students participating in the Nuclear Energy Training Program and two faculty members for research participation appointments. ORNL also continues to participate in the pre-co-op scholarship program for minority students in engineering by providing summer employment to those who will be entering school at one of the participating HBCUs.

Basic Physical Sciences Programs

Basic Energy Sciences

Basic Energy Sciences supports a wide variety of research in nuclear science, material science, chemical science, engineering and geosciences, applied mathematical science, and advanced energy projects.

The **Nuclear Sciences Program** supports the major isotope production facilities' HFIR–Transuranium Processing Plant (TPP) and the calutrons, as well as the Oak Ridge Electron Linear Accelerator (ORELA), a national user facility available to physics and energy researchers for fission- and fusion-related nuclear data measurements. Full 12-month operating cycles are planned for the calutrons to replenish the sales and research materials collection inventories.

The most significant addition to the **Materials Science Program** is the R&D program for a **new research reactor for the Center for Neutron Research (CNR)**, a proposed national user facility and an ongoing ORNL initiative. This program's goal is to design the world's best reactor for neutron scattering research and to improve current capabilities for isotope production and materials irradiation studies.

The R&D program will be a collaborative effort involving resources and personnel from institutions including ORNL, Argonne National Laboratory (ANL), Brookhaven National Laboratory (BNL), Idaho National Engineering Laboratory (INEL), and Los Alamos National Laboratory (LANL). Major areas of emphasis are design of the core, cold source, and hot source; selection, manufacture, and qualification of fuel; corrosion/erosion studies of fuel-cladding materials, including investigation of various methods to reduce corrosion; tests and analyses of thermal hydraulics; validation of

ORNL budget outlays and full-time equivalent personnel projections for Biomedical and Environmental Sciences Programs are shown as a percentage of the total ORNL budget outlay and full-time equivalents.

Michael Santella, principal investigator, and L. C. Manley inspect some of the experimental apparatus used at ORNL to study the brazing characteristics of ceramics. A brazing process developed at ORNL has been used to fabricate 11.2-cm-diam joints between zirconia and cast iron at a temperature of only 735°C. The shear strength of these joints is near 200 MPa at room temperature.

grow as more complex and sophisticated microanalyses are required for studies of interfaces, ceramic and composite materials, and ordered alloys. Addition of an atom-probe field-ion microscope will open new avenues for materials research on the atomic level. The potential of synchrotron radiation at the National Synchrotron Light Source (NSLS) for characterization of surfaces/interfaces and development of an X-ray microprobe will be exploited.

Surface-related phenomena and semiconductor materials are important frontier research areas. Completion of a building expansion for the **Surface Modification and Characterization (SMAC) Collaborative Research Facility** will allow installation of an implantation accelerator and a dedicated Ion Beam Deposition (IBD) system and a computer/data analysis center. Fabrication and characterization of thin films and artificially structured

shielding analyses and neutronics performance predictions through critical experiments; tests and analyses of structural elements; and safety studies. The goal is to design a reactor with a useful thermal neutron flux up to a factor of 10 higher than is currently available for neutron scattering while retaining the neutron spectrum and flux requirements for materials irradiation studies and transuranium isotope production. Higher fluxes will allow neutron scattering studies of smaller specimens with higher resolution for many applications than are currently possible. In addition, studies of real-time processes will become feasible. Other design characteristics will be optimized to meet anticipated user requirements.

Development and utilization of neutrons and other analytical materials characterization techniques will also show increased activity. **Electron microscopy** will continue to

Bob Laxson, Chemical Technology Division, observes the progress of an ion-exchange step used to purify ^{252}Cf in the TURF Californium Facility. All ^{252}Cf used in the western world is purified in the TURF Californium Facility.

materials formed by IBD will continue. Installation of a second beam line on the tandem accelerator in the SMAC facility will permit high-energy implantation of heavy elements. Upon completion of planned modifications, integrated materials processing and in situ materials

characterization techniques will be possible. Planned expansions include growth in the area of ion beam processing of metal surfaces. Substantial theoretical research will continue to relate to surface science, ion implantation, random alloys, and radiation effects.

Ceramic materials exhibit growing technological importance. In addition to property enhancement with surface modification, development of novel processing and property measurement techniques is investigated. Planned expansion of these programs includes development of an analytical model for sintering zirconia-toughened composites, including solute stabilizer effects. Development of ceramic materials and aluminide-based alloys for high-temperature applications with concurrent technology transfer efforts will continue at the current levels.

During this period, the **Low Temperature Neutron Irradiation Facility (LTNIF)** will become fully operational. Fundamental irradiation effects studies of pure metals, insulators, and transition metal carbides and nitrides are planned.

The **Chemical Sciences Program** supports tasks in physical chemistry, atomic physics, chemical energy, and separations and analyses. Growth is anticipated in the atomic physics and separations and analyses areas. The Atomic Physics Program performs accelerator research on the EN Tandem and the Holifield Heavy Ion Research Facility (HHIRF). Completion of the design and initiation of construction of a Heavy-Ion Storage Ring for Atomic Physics (HISTRAP) at HHIRF are planned. The HISTRAP, an ongoing ORNL initiative, is an advanced facility for the study of the atomic physics of multicharged ions. This area of study is important in basic science research, magnetic fusion studies, atomic data verification, and X-ray laser development. The goal of HISTRAP is to provide intense, high-quality currents of highly charged ions. To date, the conceptual design report and related documentation have been completed for this facility. HISTRAP will consist of a synchrotron cooling ring (48-m circumference) to store beams of multicharged heavy ions supplied by the Tandem Accelerator

David Vick, Analytical Chemistry Division, works with the contained spark-source mass spectrometer that was developed for qualitative and quantitative analysis of highly radioactive materials. This is the only instrument of this kind in the free world.

of HHIRF or by a dedicated Electron Cyclotron Resonance-Radio Frequency Quadrupole System. In addition, HISTRAP will provide the capabilities for exciting new experiments involving ion-atom interactions, low-energy multicharged ion beams, merged beam ion-ion collisions, and spectroscopy. HISTRAP will operate as a national user facility in a manner similar to HHIRF.

A new project initiated in FY 1986 is the development of a high-intensity, slow-positron source at ORELA. This source will provide two orders of magnitude more flux than conventional radioactive sources. Construction of the **Advanced Mass Spectrometry Laboratory** at ORNL will centralize mass spectrometry research, modernize the equipment in these programs, and foster collaboration with industries and universities. A new program in the organic mass spectrometry area is development of a translational spectrometer for studies of the collisional activation excitation process, the cornerstone of the mass spectrometry/mass spectrometry (MS/MS) technique. **Chemical energy research** will emphasize studies of fossil fuel chemistry, separative processes, catalysis, and solution behavior at high temperatures and pressures.

In the **engineering and geosciences** subtask, research avenues for the Center for Engineering Systems Advanced Research (CESAR) include assembly and characterization of a remote manipulator, development and application of parallel algorithms for robotic tasks (e.g., navigation and vision), and continued evolution of the Hostile Environment Robotic Machine Intelligence Experiment Series (HERMIES). The Geosciences effort emphasizes experimental geochemistry with limited field work related to continental scientific drilling experiments. A new project

C. E. Klabunde and H. R. Kerchner, Solid State Division, are shown preparing the cryostat for a low-temperature irradiation at the Low Temperature Neutron Irradiation Facility. The Bulk Shielding Reactor core is glowing and is in a standby position to the left of the cryostat.

Ray Padgett, Metals and Ceramics Division, performing elemental surface analysis on a Ni_3Al grain boundary using the 590 Scanning Auger Microprobe System.

will involve study of oxygen/hydrogen systematics in brines in geothermal and hydrothermal systems.

Expansion into the **advanced energy projects** subtasks will enable study of methods for the recovery of cellulase, an enzyme for the hydrolysis of cellulose, from aqueous solution and undigested solid residues. **Applied mathematics** programs are also expected to grow, with increasing emphasis on the development of basic algorithms and communication techniques for parallel computing. A new area of emphasis will be the development of techniques for applying parallel computing to problems involving partial differential equations. Collaborations through the UT-ORNL Distinguished Scientist

Program will contribute to this program, especially in the area of sparse matrix calculations.

Nuclear Physics

Heavy ion physics is the major research area supported by the Nuclear Physics Program. HHIRF, operated as a national user facility, is the focus of much of the experimental program. Increased interactions between UTK and ORNL include the Distinguished Scientist Program, the UT Center of Excellence, and the Joint (ORNL-UTK-Vanderbilt) Institute for Heavy Ion Research. An increased research effort will exploit the Compton Suppression System incorporated into the spin

spectrometer, the HILI (Heavy Ion/Light Ion) Detector, and the higher energies made available by the extended-tube upgrade of the 25-MV tandem electrostatic accelerator. The theory effort will continue to develop techniques for utilization of the VAX/array-processor system for large theoretical physics calculations. The light ion physics group will continue to concentrate on studies of giant nuclear multipole resonances and charge-exchange reactions. It is anticipated that the HHIRF will continue to be used by DOD and NASA to investigate semiconductor junction response with single-event-upset experiments. During this period, the **relativistic heavy-ion experiment** at CERN will come to fruition. Calorimeters designed and constructed at ORNL are an important part of this international, collaborative effort. After completion of the approved experiments at CERN, planning for future relativistic heavy-ion experiments will most likely center on the Alternating Gradient Synchrotron (AGS) plus booster facility at BNL.

A major new proposal for construction is an **intermediate-energy heavy-ion upgrade** to the Holifield facility. This proposal is an extension of the Heavy-Ion Booster Synchrotron and Storage Ring Proposal presented last year. The principal components of this upgrade are a 15-Tm booster synchrotron and a 10-Tm storage ring. The proposed system, developed in conjunction with the Holifield users' group and a broad spectrum of the heavy-ion physics community, would supply high-quality ion beams with energies up to 1500 MeV/nucleon for light ions and 900 MeV/nucleon for heavy ions. The area of physics addressed by this proposal has been identified by the DOE National Science Foundation (NSF) Nuclear Physics Advisory Committee as a high-priority area for development.

High-Energy Physics

The High-Energy Physics Program includes basic research for the study of elementary particles and supports a group that provides the high-energy physics community with calculated data and develops computer codes for cross sections and transport phenomena. The latter is essential for the design of effective detector calorimeters and high-energy accelerator radiation shielding. The elementary particle studies are part of a collaborative program based primarily at UTK.

Energy Research and Analysis

The Energy Research and Analysis Program supports technical and economic assessments of alternative energy technologies. Evaluations are conducted in response to specific requests from DOE-OER.

ORNL budget outlays and full-time equivalent personnel projections for Basic Physical Sciences Programs are shown as a percentage of the total ORNL budget outlay and full-time equivalents.

Reflections and Projections

Strategic View

Within the next several years, energy will once again become a very important R&D area. Energy supplies in the United States and the world will tighten substantially toward the middle of the planning period, and conditions will be right for another round of energy crises. As before, the central issue will be liquid fuels and the production and efficient use of liquid fuels will become focal points for a revived energy R&D program. In the electrical energy area, the rest of the world will continue to accelerate the movement toward nuclear energy, and it will become evident that this nation's forfeiture of its leadership position in nuclear technology cost it dearly in terms of lost opportunities in international trade and lost influence over important matters such as direction, safety standards, and fissile material control. This realization on the part of our federal government will result in a revitalized national effort in fission power reactors. Fusion energy R&D will continue to be an important activity with a strong element of international cooperation and collaboration. Near the end of the planning period, a large superconducting advanced toroidal

fusion experiment will be completed in the Oak Ridge area.

The question of hazardous chemical and nuclear wastes will continue to be nationally important throughout the remainder of this century and beyond. The Laboratory has created a center to cooperate with private-sector research to lead in developing techniques and technologies for neutralizing existing hazardous waste sites. These objectives will be the top priority for the national R&D wastes program. Efforts related to the waste problems will produce a better understanding of natural water systems and will lead to new areas of research on dilute and dispersed insults and on needs and mechanisms for improved water use and conservation.

Arms limitations agreements will be reached with the Soviet Union, and the production and deployment of nuclear weapons will decline. Nevertheless, defensive weapons R&D will continue to be a large and very important national activity.

Important new R&D opportunities will develop in a number of fields, including computational areas such as artificial intelligence (AI), robotics, teleoperations, intelligent machines, and parallel computing. These areas offer the means by which the United

States can once again be an international industrial leader.

Laboratory Boundaries

ORNL will remain a government-owned, contractor-operated R&D institution throughout the 15-year planning period. The federal agency responsible for ORNL will be DOE or a successor agency. A large part of the work carried out at the Laboratory will be for DOE, but a substantial amount of work for others will be permitted. Energy R&D will continue to be the central theme of the Laboratory's work, but other closely related civilian and military R&D activities will be important. The defense R&D opportunities will be in areas other than nuclear weapons, which will continue to be handled by the weapons laboratories. Basic physics research will continue to be a Laboratory priority. The conception, design, construction, and operation of unique national user facilities will remain an important part of ORNL's charter. Collaboration and cooperation with researchers from academia and industry will continue to increase.

The relationship of ORNL to other components of Energy Systems

will undergo evolutionary changes that will result in a much stronger capability to undertake large, complex projects. The Laboratory will become the center for advanced developmental activities for Energy Systems, and the other facilities will play the project and production roles.

The major change in character of the Laboratory over the next 15 years will be a shift toward major technological missions in energy and in related defense areas. Broad goals in these areas follow:

- To preserve and advance nuclear power through R&D directed toward developing a new generation of economical, reliable, and safe power reactors; ensuring safe and reliable long-term operation of current light-water reactors; removing waste storage and disposal as an impediment to the expansion of nuclear power; applying advanced nuclear systems to space applications; and becoming increasingly involved in the international fission program.
- To become the developer of a net-power-producing magnetic fusion reactor, with particular emphasis on R&D support for the next major fusion experiment through developing magnets, heating concepts, fueling prototypes, and materials; leading the reactor design efforts; conducting innovative toroidal experiments; and hosting a large U.S. or international fusion experiment.
- To conduct advanced development work in important focused areas of nonnuclear energy technologies such as fossil energy (with emphasis on materials, environmental and health effects, environmental control technologies, and innovative research on coal chemistry related to the production of liquid fuels) and conservation

and renewables (with emphasis on high-temperature materials, conservation in buildings, biomass production, and electric energy systems).

- To create a strong technological base in generic areas of energy development in support of these technologies by conducting basic and applied research in materials sciences (alloys, ceramics, and composites) including hosting large user facilities such as the HTML and the CNR; separations sciences (chemical, biological, and mechanical processes); computational sciences (artificial intelligence, parallel processing, intelligent machines, networking, and information science); and measurement sciences (controls and sensors).
- To identify and understand important environmental and health

effects associated with the energy areas of emphasis, including basic and applied biological research on genetic and somatic effects of radiation and chemical exposures; relationships of primary energy effluents to global environmental issues; development of human health and environmental assessments and risk analyses in these areas; and development of advanced instrumentation, measurement techniques, and methodologies for applying nuclear technologies to medical diagnosis and treatment.

- To carry out basic research in nuclear physics, with emphasis on heavy ion and neutron physics.
- To contribute to the development of defensive weapons through major R&D activities on space power sources, energy storage, neutral particle beams, and rail guns.

Plant and Equipment Division riggers position a template over the newly constructed greater confinement auger hole facility in a solid waste storage area. Triple containment (cast iron, concrete backfill, and concrete tile) is provided for the waste.

- To become an important R&D center for nuclear and nonnuclear wastes, emphasizing surface storage of nuclear wastes and using DOE's R&D center for hazardous chemical wastes, involving the Oak Ridge Model.
- To actively transfer technologies and techniques to American industry by means of an active association with industry, including working for industry and consortia; user facilities; and ties with selected universities and consortia of universities; and an aggressive patent and licensing policy.

Long-Range Implications

Expected changes in program areas over the next 6 years are depicted in Figs. 6-8. By the end of the 15-year planning period, the Laboratory is expected to be as much as 50% larger than it is now. Growth is projected to be primarily in the technology areas, including fission, fusion, fossil, defense, and wastes. Growth areas in the fundamental research programs include development of new materials and characterization techniques, investigations of atomic processes, evolution of robotics, and investigations of bioprocessing. In the energy areas, even stronger international collaboration is anticipated as projects become larger and as the United States competes with foreign science and technology.

Some shifts in sponsorship will take place over the next several years, reflecting participation by the Laboratory in important R&D activities outside energy (primarily in defense and in waste management). Nevertheless, DOE will remain ORNL's largest and most important sponsor.

Fig. 6. Trends and projections of ORNL program funding.

Fig. 7. ORNL program funding for FY 1980 and 1986 and projections for 1992.

Fig. 8. Total ORNL budget outlay distribution by sponsor for the period FY 1980-1992.

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