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TRENDS & BALANCES · 1985-1990

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Cover: An artist's conception of new directions for science and technology at Oak Ridge National Laboratory. For more detailed information, see New Initiatives.
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TRENDS & BALANCES · 1985-1990

January 1985

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Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831
operated by
Martin Marietta Energy Systems, Inc.
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Acronyms

AD	Associate Director	HTML	High Temperature Materials Laboratory
ATF	Advanced Toroidal Facility	IET	Integrated Equipment Test
BER	Building Equipment Research	LCTF	Large Coil Test Facility
BNL	Brookhaven National Laboratory	LLNL	Lawrence Livermore National Laboratory
BRET	Breeder Reprocessing Engineering Test	LMR	liquid-metal reactor
BTESM	Building Thermal Envelope Systems and Materials	LWR	light-water reactor
CBCF	carbon-bonded carbon-fiber	MHTR	modular high-temperature reactor
CDIC	Carbon Dioxide Information Center	NEPA	National Environmental Protection Act
DHHS	Department of Health and Human Services	NRC	Nuclear Regulatory Commission
DOD	Department of Defense	NSF	National Science Foundation
DOE	Department of Energy	OCRWM	Office of Civilian Radioactive Waste Management
DON	Department of the Navy	OER	Office of Energy Research
EBS	Elmo Bumpy Square	OHER	Office of Health and Environmental Research
EBT	Elmo Bumpy Torus	ORGDP	Oak Ridge Gaseous Diffusion Plant
ECR	Electron Cyclotron Resonance	ORNL	Oak Ridge National Laboratory
EPA	Environmental Protection Agency	ORO	Oak Ridge Operations
ETP	Emergency Technology Program	PNL	Pacific Northwest Laboratory
FEDC	Fusion Engineering Design Center	PPPL	Princeton Plasma Physics Laboratory
HCDWMP	Hazardous Chemical Defense Waste Management Program	PWR	pressurized-water reactor
HCW	hazardous chemical waste	R&D	research and development
HFIR	High Flux Isotope Reactor	RCS	Residential Conservation Service
HHIRF	Holifield Heavy Ion Research Facility	SDP	Site Development Plan
HTGR	high-temperature gas-cooled reactor	TFTR	Tokamak Fusion Test Reactor
		TRU	transuranium

A new building at Oak Ridge National Laboratory, the Surface Sciences Laboratory, provides light laboratory and office space for Solid State Division personnel.

Preface

This is the seventh edition of *Trends and Balances* to be presented to the staff of Oak Ridge National Laboratory (ORNL) and other interested parties. Each year at the end of the planning cycle the Laboratory publishes its official planning document, the *Institutional Plan*. *Trends and Balances* is brought out as a condensation of that more formal document and is intended to provide a reference to the kinds of plans that have occupied senior Laboratory management over the past year.

An institution as large as ORNL changes slowly, so some of the information in this document overlaps that contained in the previous edition of *Trends and Balances*. Much, however, is different. A new section, for example, describes what senior Laboratory management feels are five new directions for science and technology at ORNL. This document is intended to provide new insights into the programs and structure of the Laboratory.

J. W. Terry
Program Planning
and
Analysis Office
January 1985

Director's Statement

This past year has been an especially eventful one for the Oak Ridge National Laboratory (ORNL). On April 1, 1984, Martin Marietta Energy Systems, Inc., assumed responsibility for ORNL and its three sister Department of Energy (DOE) facilities. The transition from Union Carbide Corporation, operating contractor for 38 years, to Energy Systems was a smooth one for a number of reasons. First, DOE staff, both locally and at Headquarters, did an excellent job of planning and preparing the way for the changeover. Second, Union Carbide and Energy Systems worked closely together to make the transition as smooth as possible. And third, the ORNL staff exhibited the patience and understanding necessary to traverse the inevitable rough spots without losing momentum.

The year was also outstanding from the standpoint of science and technology. We won four I-R 100 awards, which for the third year in a row tied for the most wins of any organization in the country. Our work on thermal shock in reactor pressure vessels may save the

country billions of dollars because it showed that certain vessels need not be withdrawn from service prematurely. In fusion we had our best year ever. The Large Coil Test Facility—a facility that involves international collaboration—was completed within the time and budget established three years ago. A pellet fueling device developed at the Laboratory was a key ingredient in the achievement for the first time of a combination of plasma density and confinement time that exceeded the “Lawson” criterion. In the materials area, a number of exciting things are in the works, including the establishment of working relationships with a number of private firms for the transfer of the technologies associated with nickel-aluminide alloys.

And what is the outlook for the future? The arrival of Energy Systems coincided nicely with the fruition of movements set afoot in Washington following completion of three national studies of DOE's multiprogram laboratories. As a result, the contract has fewer restrictions, so we can do a better job for DOE. We are particularly pleased with some of the measures to allow more flexibility commensurate with greater accountability. One manifestation of this is our expanded Exploratory Studies Program, which allows us for the first time to undertake certain kinds of projects that can have a strong influence on our future. An example is the recently completed preconceptual design study of the High Flux Isotope Reactor-II.

Although the Laboratory's long-term outlook is excellent, the reality of the huge federal deficit cannot be ignored. Belt tightening will be needed across the board, including in research and development (R&D) expenditures. I look for very tight budgets in FY 1986 and FY 1987. We can survive this period with our strategic skills and physical resources intact if

we put renewed emphasis on program development; we need to develop some new program areas as well as to expand selected existing ones.

Beyond the next two years we will likely have some new growth. The overall energy picture in the United States and the world is slowly changing from an oil glut to a more normal situation. In fact, the continuing U.S. economic recovery has meant an enormous electrical growth rate and consequently a renewed concern for the adequacy of electrical capacity. Current global environmental issues (carbon dioxide, acidic deposition, and other atmospheric phenomena)

call into question the simple extension of past practices into the future. These issues, coupled with the volatility of the Middle East and the worldwide economic recovery, suggest that energy will once again have a high profile and that energy R&D will be viewed with new urgency. The only question will be, Why were we not doing these things when we had a breathing spell?

A handwritten signature in dark ink, appearing to read "Herman Postma". The script is cursive and somewhat stylized, with the first name "Herman" being more prominent than the last name "Postma".

Herman Postma

Laboratory Overview

Major Achievements

Oak Ridge National Laboratory (ORNL) programs routinely produce high quality work. A number of activities reaching completion or accomplishing a critical development stage during FY 1984 were of sufficient magnitude to be described as major achievements. The following were among them.

Three-coil test completed in the Large Coil Program. The first major integrated operation has been accomplished in the Large Coil Test Facility (LCTF), a facility for testing superconducting magnets to be used in a fusion energy reactor. The coils were operated at 4.2 K. The first three coils—from Japan, Switzerland, and the United States—have been shown to be operable in the LCTF. International collaboration in the development of superconducting magnets for fusion is working well. Useful, new information has been obtained from tests of the Japanese and U.S. coils to full design current. The LCTF will be suitable for testing a full six-coil array under simulated tokamak conditions.

Effects of air pollution on tree growth. An investigation of the historical patterns of element composition in tree rings from the Great Smoky Mountains National Park was performed using Inductively Coupled Plasma-Optical Emission Spectroscopy. Annual growth rings from shortleaf pine trees showed suppressed growth and increased iron content between 1863 and 1912, a period of smelting activity and of large sulfur dioxide releases at Copperhill, Tennessee, 88 km upwind. Similar growth suppression and increases of iron and other metals were found in rings formed in the past 20 to 25 years, a period when regional fossil fuel combustion emissions increased about 200%.

Pressurized thermal-shock tests and analytical evaluations in support of the Nuclear Regulatory Commission's (NRC's) safety studies of light-water reactor (LWR) pressure vessels. A pressurized thermal-shock test facility has been constructed and operated successfully to produce crack initiation and arrest events in a deliberately flawed pressure vessel under realistically combined thermal and pressure loadings. Data obtained have shown, subject to confirmation and use by NRC for regulatory purposes, that the LWR vessels most sensitive to thermal shock may not have to be withdrawn from service prematurely.

An analytical evaluation of the Oconee-1 nuclear power plant was performed to provide NRC with an independent, balanced assessment of pressurized thermal-shock phenomena in pressurized-water reactors (PWRs) built by three U.S. vendors. This pioneering study combined probabilistic and deterministic methods to calculate the frequency of through-wall cracks in a PWR pressure vessel with a 95% confidence interval. Based on the results of this study, pressurized thermal shock does not appear to be a specific problem at Oconee-1. This study has application to 11 reactors being considered by NRC for the imposition of expensive mitigating actions. The monies saved as a result of this study amount to roughly \$3.3 billion.

Multilayer relaxations in metallic surfaces. The precise determination of atomic positions in surfaces is central to the understanding of surface electronic distributions and the electronic behavior of materials. Significant theoretical and experimental advances have recently been made at ORNL in the application of low-energy electron diffraction to surface crystallography. These advances have allowed the determination of atomic positions in surfaces to better than 2 pm,

two to five times better than previous determinations. The results universally indicate contraction between the first two layers, and expansion between the second and third layers compared to atomic spacing in the bulk. These procedures were recently used to predict and observe for the first time an atomic rippling at the surface of an ordered metallic alloy.

Centrifugal pellet injector. This device for fueling fusion experiments was used to achieve the first demonstration of steady-state pellet fueling in the Doublet-III (D-III) tokamak at GA Technologies. The plasma density achieved in the initial experiment exceeded the highest value achieved to date using the traditional gas injection technique. The injector worked the first time it was tried.

Protein engineering. The achievements in protein engineering include (1) the cloning of the gene for the carbon dioxide fixation enzyme (ribulose biphosphate carboxylase) in *E. coli* and observing the expression of an authentic native enzyme; (2) the chemical syntheses of several short segments of the gene that encodes the desired changes in enzyme structure; and (3) the preparation of an antibody to the carbon dioxide fixation enzyme so that mutant forms, which might be catalytically inactive, can be assayed.

Advanced servomanipulator development. The Advanced Servomanipulator represents a new generation of remote-handling technology by providing improvements in reliability and remote maintainability while attempting to maintain high-quality force reflection similar to that of mechanical master-slave manipulators. The new manipulator is unique, with its extensive use of precision-gear, torque-tube power transmission. An improved control system has been developed using the latest 16-bit microprocessor to provide many new automation features—including robotic operation for repetitious tasks, on-line self-diagnosis, and automatic television-camera tracking.

Terrestrial radioisotope application development. Radioluminescent light fixtures were developed and tested for use as landing lights at remote airfields. The state of Alaska plans to

implement the general use of these lights for remote airfields.

Persistent discrepancies in nuclear data resolved. Discrepancies among the values of nuclear parameters for ^{238}U have introduced significant uncertainties in breeder reactor design. A careful, thorough reexamination of the most recent ORNL, European, and Japanese data has shown that most of the apparent discrepancies were caused by differences in the analysis procedures. The newly acquired confidence in the ^{238}U parameters will enhance confidence in reactor designs and thereby serve to lower the cost of future reactors.

ISX-JET beryllium limiter test. The multinational European Economic Community Joint European Torus (JET) project funded a program on the ISX-B (Impurity Study Experiment) tokamak to test the properties of a beryllium limiter. The test involved determining the response of the limiter to a substantial fluence of energetic plasma ions and characterizing the behavior of the plasma in comparison with titanium carbide-coated graphite as a limiter material. The design and production of the limiter were undertaken in collaboration with Sandia National Laboratories. The tests showed that, provided the beryllium is kept below its melting point, it can support a plasma with similar characteristics to the titanium carbide-coated limiter. In addition, if beryllium is melted from the limiter, it acts as a getter, trapping impurities such as oxygen and nitrogen on the walls of the vacuum vessel. Finally, even though the surface of the limiter was substantially melted in early tests, the limiter withstood the ion fluence required by JET.

Molecular biology of leukemia. A mutant mouse stock developed by ORNL that will allow for the isolation of somatic hybrid cell clones was recently recognized and established. The use of this mutant mouse stock has made possible the isolation of the Fv-1 gene, which is responsible for inhibiting the murine leukemia virus and thereby preventing leukemia in the mice.

Integrated Equipment Test (IET) facility constructed. The construction phase of the IET

facility was completed more than four months ahead of schedule. The facility will provide an intermediate step between prototype development and final design of equipment and components suitable for use in the reprocessing of fast breeder reactor fuels. The experience gained from operating the nonradioactive IET facility will be used to increase the reliability and reduce the time for initial startup of the radioactive reprocessing facility by providing for extensive integrated testing of both remote maintenance and operational aspects of a major portion of the process equipment.

Multielement electromagnetic isotopic enrichment. A new technique for utilizing a segment of eight electromagnetic isotope separators to enrich simultaneously the isotopes of several neighboring elements has been implemented. The primary benefit from this mode of operation is that research requirements for small quantities of numerous isotopes can be met in a more timely fashion without jeopardizing the availability of the isotopes required by the medical community for health care delivery.

Gamma-decay of nuclear giant resonances. In FY 1984, ORNL made the first detailed measurements of nuclear giant resonance gamma-decay, using unique instrumentation at the Holifield Heavy Ion Research Facility (HHIRF). The measurements were performed by inelastic scattering of 350- and 400-MeV ^{17}O projectiles from ^{90}Zr and ^{208}Pb targets. The availability of a high-energy ion beam at the HHIRF and the ORNL Spin Spectrometer (a 72-detector "crystal ball" array) was essential in performing these experiments. The results provide important data for testing theories of the giant resonance behavior of nuclear matter.

Advances in nickel-iron aluminides. Major advances have been made in the development of ductile, high-strength nickel-iron aluminides in three areas: (1) the alloy can be fabricated using existing industrial practices following the finding of enhanced hot fabricability by controlling the iron-to-nickel ratio and by making small additions of rare earth elements such as cerium; (2) the welding of this class of alloys without cracking has been demonstrated for alloys that

have had the boron content reduced from 500 ppm to 200 ppm; and (3) the alloy can be made to perform well in a sulfidizing atmosphere by preoxidizing the surface to form a protective aluminum oxide scale.

Cell kinetics in the lungs of mice treated with bleomycin. The anticancer drug bleomycin produces acute and chronic lung damage. To better understand the production and development of the disease, a cell-kinetic analysis of mouse lung was performed. To test for the pathway producing more damage, the bleomycin was given by two different routes, intravenously and intratracheally. The intratracheal route leads to earlier cell damage. The activity of several enzymes measured in fluid removed from the lungs, pulmonary lavage fluid, paralleled cell proliferation in lungs.

Completion of preconceptual design of the Breeder Reprocessing Engineering Test (BRET). BRET is a collaborative effort with Hanford Engineering Development Laboratory designed to support the breeder reprocessing technology development and close the fuel cycle for the Fast Flux Test Facility (FFTF) and succeeding breeder demonstrations. Closing the fuel cycle will reduce the amount of high-level nuclear wastes.

Electron cyclotron resonance multicharged ion source. The Electron Cyclotron Resonance (ECR) multicharged ion source is fully operational at its design frequency of 10.6 GHz. The ECR ion source is used in measurements of total electron capture cross sections for fully stripped light ions incident on atomic hydrogen. Such collisions represent true three-body systems and thus are of great theoretical interest, as well as having practical application in controlled fusion research.

Lead-iron phosphate glass. A new lead-iron phosphate glass nuclear waste form has been developed that appears to be unusually well suited to the safe immobilization and permanent disposal of high-level nuclear wastes. An outgrowth of research on preparation of synthetic monozites, the new waste form chemically incorporates the radioactive nuclei in the glass structure. Relative to the borosilicate nuclear waste

glasses that are currently the "reference" waste form for the long-term disposal of nuclear wastes, lead-iron phosphate glasses have several distinct advantages: (1) an aqueous corrosion rate that is about 1000 times lower, (2) a processing temperature that is 100–250°C lower, and (3) in the temperature range 800 to 1000°C, a melt viscosity that is much lower. The lead-iron phosphate waste form can be processed using technology similar to that developed for borosilicate nuclear waste glasses.

Navy Civilian Personnel Data System Project. The Navy Civilian Personnel Data System Project was established by the Department of the Navy (DON) to develop and implement a single centralized computer system to support all DON civilian personnel offices worldwide and at various command and headquarters offices. Through the efforts of a staff composed of ORNL and subcontractor personnel, the computer facility was established and services were begun to the first Navy site to have its data entered into the system. The system, which replaces three obsolete Navy-wide systems and numerous single-site systems, was credited by the Assistant Secretary of the Navy with saving the Navy in excess of \$20 million in development costs.

Visible laser determination of ultraviolet optical parameters. A new laser technique has been developed for the accurate, simultaneous determination of optical oscillator strengths, indices of refraction, and absorption coefficients for atomic and molecular species in the vacuum ultraviolet, 100-nm to 200-nm, spectral region. The new studies allow one to use high-intensity visible laser light to obtain information on atomic response at three times the laser frequency. Detailed information on optical parameters in ultraviolet spectral regions is important in pure and applied areas of science and technology such as the production of high-energy photons by laser methods and the technology of excimer lasers and excimer amplifier development for research and commercial purposes.

Development of ceramic-to-metal joining process. A major technological problem with the adiabatic diesel engine concept has been the dif-

ficulty of reliably joining insulating ceramics to critical engine components. Surface preparation and brazing processes that can be used to join a partially stabilized zirconia ceramic piston cap to a ductile iron piston have been developed at ORNL. Tests on brazed samples have shown that the shear strength of the braze meets the design requirements. This work is being done in cooperation with Cummins Engine Company, developer of the adiabatic diesel engine.

Photoelectron dynamics of manganese. The most comprehensive experimental study to date of the photoelectron dynamics of a transition metal atom has been completed for the case of manganese. The manganese atoms were exposed to synchrotron radiation, and a determination of the energy and angular distribution of the emitted electrons as a function of the excitation energy was made. The analysis gives the partial photoionization cross sections and the angular distribution parameters for both single-electron and two-electron transitions. This study represents the first time that absolute partial cross sections have been determined for a metallic vapor. Comparison of the data with predictions from various existing theoretical models showed the best overall agreement with a many-body perturbation theory model despite a number of discrepancies. Such experimental data present a stringent test of chemical theory.

Measurement of DNA single-strand breakage in mouse and human sperm. While methods have been proposed that will detect chromosomal damage in somatic cells of exposed human beings, to date no validated procedures exist for detecting such damage induced in germ cells where the damage would be potentially heritable. Alkaline elution, a technique originally used to measure DNA single-strand breaks induced in cultured body cells, has now been adapted to measure DNA strand breaks induced in mammalian sperm cells after in vivo exposures to chemical agents. In order to test the applicability of the procedure to human subjects, DNA single-strand breaks have now been assayed in human sperm. The DNA single-strand breakage measurements may prove to be useful in monitoring human males for genetic

damage resulting from exposures to environmental agents.

New proposal in transeinsteinium chemistry. Neutron cross sections were measured for ^{253}Es and ^{254}Es that considerably revised the values presently in the literature. These new cross sections show that it is feasible to increase the production of ^{254}Es by a factor of 10 to reach about 40 μg per campaign. Because of its large number of protons and neutrons, ^{254}Es makes an excellent target for use in heavy-ion accelerators for the production of isotopes in the transeinsteinium region of the periodic table for chemical and nuclear studies. ORNL and several other national laboratories have proposed that the ^{254}Es be produced to make the transeinsteinium investigations possible.

Laboratory Roles

R&D Activities

The primary role of ORNL is to carry out applied research and engineering in fusion, fission, and other energy technologies, and scientific research in basic physical and life sciences. To fulfill this role, 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, development of prototype superconducting confinement magnets, and testing of candidate first-wall and blanket materials; (2) nuclear fission, focused on development of nuclear fuel reprocessing, materials testing and development for high-temperature gas-cooled and advanced converter reactors, and technologies for managing nuclear waste; (3) biological and environmental 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) fos-

sil energy, focused on development of materials for fossil fuel applications and on health and environmental effects of coal conversion systems; and (6) basic research in physical sciences, with emphasis in materials research on radiation effects, neutron scattering, surface physics, and high-temperature materials; in chemical sciences on aqueous solutions; and in nuclear physics on heavy-ion reactions.

ORNL designs and provides research facilities for the benefit of members of the scientific and technical community and interacts closely with scientific personnel in universities and industry. Research facilities having funding to support the activities of outside users include the Bioprocessing Research Facility, the EN Tandem Accelerator, the Health Physics Research Reactor, the HHIRF, the National Center for Small-Angle Scattering Research, the Neutron Scattering Facility, the Oak Ridge Electron Linear Accelerator, the Oak Ridge National Environmental Research Park, the Shared Research Equipment, and the Surface Modification and Characterization Facility. During FY 1984, more than 300 scientists from throughout the world performed experiments at ORNL user facilities.

In addition to the above activities for the Department of Energy (DOE), ORNL does work for other federal agencies, state and local governments, and private concerns. The Laboratory performs this "Work for Others" in areas of significant expertise that are consistent with the interests of DOE. A major portion of this Work for Others is performed for the Nuclear Regulatory Commission (NRC). Other major federal users of ORNL expertise are the Department of Defense (DOD), the Department of Health and Human Services (DHHS), the Environmental Protection Agency (EPA), and the National Science Foundation (NSF). Work for Others constitutes approximately 20% of the funding for ORNL.

The interactions between ORNL and the university community provide a means for the transfer of information formally through programs and informally through professional association. University guests may participate in

FY 1984
TOTAL: 1993 DIRECT FTEs

Fig. 1. The Office of Energy Research supports 44% of the direct FTEs (full-time-equivalents) at the Oak Ridge National Laboratory. Other major Department of Energy (DOE) sponsors include the Assistant Secretaries for Nuclear Energy, Defense Programs, Conservation and Renewable Energy, and Fossil Energy.

ongoing research programs, perform their own experiments at the user facilities and resources, or receive instruction at state-of-the-art training facilities. This cooperative spirit is illustrated by the joint Institute of Heavy Ion Research. Located adjacent to the HHIRF, the buildings were constructed with funds from DOE, Vanderbilt University, The University of Tennessee at Knoxville, and Oak Ridge Associated Universities.

R&D Sponsors

The major sponsor of research and development (R&D) activities at ORNL is DOE. Roughly 81% of the full-time-equivalent employees at the Laboratory are funded directly by DOE (Fig. 1). The DOE Office of Energy Research (OER) has been the largest single

source of funding since 1979. OER supported approximately 44% of the Laboratory employees during FY 1984. Other major DOE sponsors are the Offices of the Assistant Secretaries for Nuclear Energy, Defense Programs, Conservation and Renewable Energy, and Fossil Energy.

Fission Energy, Basic Physical Sciences, Fusion Energy, Biomedical and Environmental Sciences, Conservation and Renewable Energy, Assessments and Analysis, and Fossil Energy constitute the major areas of work at ORNL (Figs. 2 and 3). Most of these programs receive support from several sources both within and without DOE. For example, in FY 1984 funding for the Biomedical and Environmental Sciences area came from OER, DOD, DHHS, EPA, NSF, and other federal and nonfederal sources.

The Laboratory continues to conduct research in reactor safety and radiation biology for NRC.

Fig. 2. Based on direct FTEs (full-time equivalents), Fission Energy is the largest Oak Ridge National Laboratory program area. Large operations are also carried out in many other areas.

Presently NRC is the single largest non-DOE sponsor of ORNL activities (Fig. 4). As illustrated by the diversity of funding sources noted above for the ORNL life sciences programs, ORNL has been able to enter or develop research areas through non-DOE work that have proven to be of value to DOE. The opportunity to participate in non-DOE work has provided ORNL with added flexibility at the programmatic and institutional levels.

Non-R&D Activity: The Isotope Program

From its beginning in the wartime effort to produce plutonium, ORNL has been involved in the production and isolation of isotopes. Following the war, the Atomic Energy Commission began distributing isotopes through ORNL for research purposes. As time and research pro-

gressed, the uses for radioactive and stable isotopes increased as did production capabilities. Today ORNL produces many of the radioactive and stable isotopes used throughout the world for peaceful purposes. The isotope program remains a significant ORNL role. Isotopes are distributed for use in (1) medical health care delivery as radioactive sources for treatment and both stable and radioactive tracers for diagnostic work; (2) industrial applications such as radiography of welds, radioluminescent light sources, radiotracers of flow patterns, radiogaging to determine density and content, and gamma-ray sources to sterilize packaged medical supplies and irradiate food and grain to retard spoilage and kill harmful bacteria; and (3) pure and applied research. ORNL also maintains a loan pool of stable isotopes for distribution, with the approval of DOE, to researchers performing nondestructive experiments that will not increase the radioactivity of the sample.

**FY 1984
TOTAL: \$396 MILLION**

Fig. 3. The distribution of operating monies is similar to the distribution of personnel except in those areas (e.g., Conservation and Renewable Energy) where considerable funding is spent outside Oak Ridge National Laboratory.

Technology Transfer

A Technology Transfer Program has been in place at ORNL since 1970. The activities of this program satisfy the intent of the Stevenson-Wydler Technology Innovation Act of 1980, which 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. To enhance the effectiveness of this program, a new Technology Transfer Initiative was implemented that places increased emphasis on Laboratory-industry interactions while maintaining all the existing activities of the program.

During FY 1983, Laboratory management proposed that a pool of funds be established that would be used to identify and promote ORNL efforts with commercial potential but without the funding and expertise to accomplish commercialization. Funds for this purpose became available during FY 1984, and five developments have been identified and funded.

A new consulting policy for ORNL staff allows them to consult on their own time for purposes of technology transfer. A successful application of this policy allowed an Oak Ridge area company to market a new product that had been stalled in the development stage prior to the consultation.

New working agreements with industrial firms that foster long-term research are being encouraged. Those put in place during FY 1984 were principally in the area of materials science.

The new operating contractor, Martin Marietta Energy Systems, Inc., established the Office of Technology Application with the role to place even greater emphasis on technology transfer internally and economic development externally. The primary activities of this office are associated with ORNL, and the office is responsible for technology transfer activities at the other installations operated by Energy Systems. Its objectives are to (1) motivate the inventor, (2) institute a quick, uniform value assessment procedure, (3) make technology

**FY 1984
TOTAL: \$78.4 MILLION (392 FTEs)**

Fig.4 The Nuclear Regulatory Commission (NRC) sponsors 39% of Oak Ridge National Laboratory work not performed for the Department of Energy (DOE). Together NRC and the Department of Defense sponsor 67% of the non-DOE work.

available rapidly, (4) place technology with selected clients, (5) offer protection to investing clients, (6) permit direct client assistance, (7) encourage and assist spin-off businesses, and (8) provide a modest discretionary budget to make technologies commercially attractive.

Energy R&D Outlook

Expenditures for energy by U.S. end-users amount to about \$400 billion annually, and every indication suggests that energy will continue to be an important component of the nation's economy. On a larger scale, energy is likely to become a much bigger part of the world economy. Thus in the long term, the needs and opportunities for energy R&D will clearly grow. ORNL, the largest and most diverse of the nation's energy R&D institutions, will continue to play an important role in the sciences and technologies of energy.

The long-term outlook for growth in energy R&D must, however, be tempered by the short-term reality of the growing federal deficit. Both political parties are in broad agreement on the need to restrain federal spending. This restraint, in all likelihood, will result in cutbacks in some Laboratory programs in FY 1986 and in FY 1987. At present, exactly which programs will be reduced and the extent of the reductions are difficult to determine. The Laboratory's plan is to preserve the strategic resources, including facilities and skills, needed to carry out its long-term responsibility of providing energy R&D work critical to the future well-being of the nation. Thus renewed emphasis on program development, both by expanding selected existing areas and by developing new areas, is of utmost importance. With determination and hard work by the research staff and management, ORNL has an excellent chance of bridging the upcoming lean period without serious loss of research capability.

Research and Development Programs

Laboratory Organization

The operating structure of Oak Ridge National Laboratory (ORNL) is a matrix organization in which management duties are divided along functional and program lines (see chart, p. 14). In this system, each of the four Laboratory Associate Directors (ADs) administers the technical work of specific divisions (functional line) as well as that of major programs (program line). In general, the functional role is to deploy a technical resource (skilled personnel); the program role is to use the resource to meet programmatic objectives. Because technical personnel so employed may be drawn from numerous divisions, multidivision efforts are characteristic of the ORNL research and development (R&D) approach.

Funding provided by the Department of Energy (DOE) for Laboratory work is administered through the DOE Oak Ridge Operations (ORO) office. As the Laboratory organization chart shows, each AD may also be responsible for some work sponsored by other federal agencies or nonfederal organizations.

F. R. Mynatt, the AD for Nuclear and Engineering Technologies, is responsible for the Chemical Technology, Engineering Technology, Fuel Recycle, and Instrumentation and Controls divisions. The major programs in his area are Nuclear Reactor Technology, Gas-Cooled Reactors, and Nuclear and Chemical Waste. He is also responsible for administration of the Laboratory's Nuclear Regulatory Commission (NRC) work. His DOE support comes primarily from the Assistant Secretary for Nuclear Energy, with the Assistant Secretary for Defense Programs providing funds for nuclear waste management activities.

The AD for Advanced Energy Systems is M. W. Rosenthal. He is responsible for the

Energy and Fusion Energy divisions and for the Fusion, Conservation and Renewable Energy, and the Fossil Energy programs. His sources of funding are the most diverse. They come mainly from the Assistant Secretary for Conservation and Renewable Energy, the Assistant Secretary for Fossil Energy, and the Director of the Office of Energy Research (OER). Other work under Rosenthal is carried out for the Energy Information Administration; the Assistant Secretary for Policy, Safety, and Environment; the Office of Policy, Planning, and Analysis; and the Federal Energy Regulatory Commission. Other federal agencies, such as the Department of Defense (DOD) and the Tennessee Valley Authority, as well as privately funded organizations including the Electric Power Research Institute and the Gas Research Institute, also support various activities under Advanced Energy Systems.

C. R. Richmond is the AD for Biomedical and Environmental Sciences, and he is responsible for the Biology, Environmental Sciences, and Health and Safety Research divisions. Richmond is also responsible for the following ORNL user facilities: the Bioprocessing Research Facility, the Health Physics Research Reactor, and the Oak Ridge National Environmental Research Park. His principal source of DOE funding is OER, with additional funding coming from the Assistant Secretary for Policy, Safety, and Environment. Other federal agencies, such as the Environmental Protection Agency (EPA), the Department of Health and Human Services (DHHS), and the National Science Foundation (NSF), also provide substantial support for the biomedical and environmental science work.

The AD for the Physical Sciences is A. Zucker. Divisions that report to him are Analytical Chemistry, Engineering Physics and

Oak Ridge National Laboratory organization chart.

Mathematics, Chemistry, Metals and Ceramics, Physics, and Solid State. Zucker is also responsible for several ORNL user facilities, including the Holifield Heavy Ion Research Facility (HHIRF), National Center for Small Angle Scattering Research, Neutron Scattering Facility, Shared Research Equipment, and Surface Modification and Characterization Facility. His research programs are supported chiefly through OER.

All support and service divisions report to R. S. Wiltshire, Executive Director of the Laboratory. The support and service functions, which are vital to the ORNL operation, include such diverse activities as monitoring employee health and safety; operating reactors, producing isotopes, maintaining plant and equipment; and providing information, library, and financial services. These two functions also include quality assurance activities.

Nuclear and Engineering Technology Programs

Liquid-Metal Reactor

The Breeder Reactor Systems program supports the liquid-metal (LMR) concept, with continued efforts in the traditional base-technology areas of materials, measurement and control, physics, and safety. In each of these areas, increased emphasis is being placed on activities that support innovative, low-cost, passively safe designs.

In the materials area, ORNL will maintain its role as the lead laboratory for the national Improved Materials Program and as such will continue efforts to develop and code-qualify advanced alloys, to obtain a greater understanding of the behavior of advanced structural alloys in LMR environments, and to develop improved design methods and criteria. Laboratory measurement and control activities will support the development and proof testing of key high-risk, high-payoff components and systems. Physics work will concentrate on analysis and vali-

dation of shield designs. In reactor safety, ORNL will continue to maintain data bases for safety analysis (SACRD) and component reliability (CREDO) and will obtain from the Thermal Hydraulic Out-of-Reactor Safety facility thermal hydraulics data pertinent to the understanding and management of shutdown heat removal.

High-Temperature Gas-Cooled Reactor

The goal of the U.S. Civilian Reactor Development program is to ensure the nation's energy future by establishing viable nuclear energy options and the necessary technology base. Development of high-temperature gas-cooled reactor (HTGR) options for the intermediate term is especially timely because while current light-water reactors are safe relative to other energy options, economic and regulatory problems related to safety and quality contribute to the lack of new plant orders for them.

The primary mission of the ORNL program is to provide technological expertise in support of the national HTGR program, which seeks to develop HTGRs for electricity production, cogeneration, and high-temperature process heat. The national program direction is to develop HTGRs with a high degree of passive safety and thus improve their economics and reduce risk. Within this program ORNL has the lead responsibility for the Base Technology Development Program. Technical activities include (1) performing qualification tests of HTGR fuel performance and fission product behavior under extreme accident conditions; (2) providing basic data on the mechanical, physical, and chemical behavior of HTGR materials; (3) performing component testing and development on the core support structure and on the ceramic pads on which the core posts rest; (4) providing analytical and experimental evaluation of the effectiveness of the effort of the reactor shielding design; (5) evaluating reactivity coefficients associated with various reactor conditions; and

(6) providing technical evaluations and assessments in specific as well as broad areas.

Primary program emphasis will be on developing a modular high-temperature reactor (MHTR). Current concepts consider both prismatic and pebble-bed fuel and both prestressed concrete and steel reactor vessels. Pebble-bed fuel allows on-line refueling, and steel vessels facilitate unit factory fabrication. Low core power density (4 W/cm^3) and unit power levels of 100 MW(e) in modular systems [500 MW(e) in annular systems] allow passive decay heat-removal systems. Together with the safety advantages of inert gas coolant, MHTRs should provide demonstrably wide safety margins. Safety-related regulatory issues will therefore be greatly simplified. Economic savings will result from high-quality automated factory fabrication, streamlined licensing, standardized construction, standard electrical power plant components in use outside the reactor module, incremental financing, and reduced rate-base impact.

The HTGR program achieved several major accomplishments in FY 1984. The Core Support Performance Program, which has been operated under restricted conditions, was found to be an excellent tool for obtaining information on graphite corrosion behavior under reactor operating conditions. HTGR fuels have shown promise for retaining fission products such that fewer than 1×10^{-4} of the products are released from the fuel under extreme operating conditions. Program research has shown that core support graphites can be developed that have very low oxidation rates when exposed to water vapor and that high-strength concrete can be developed using a variety of aggregate material.

Consolidated Fuel Reprocessing

The Consolidated Fuel Reprocessing Program (CFRP) plays an important role in the future of nuclear power in the United States. For about

Reginald Hall of the Chemical Technology Division conducts pilot studies of an evaporator similar to the one in Consolidated Edison's Uranium Solidification Program processing equipment. This program will solidify in a safe package over a metric ton of highly radioactive uranium solutions.

Shown with the M-2 servomanipulator are its control system developers (left to right: Paul E. Satterlee, formerly of the Oak Ridge National Laboratory; H. Lee Martin, Instrumentation and Controls Division; and Joseph N. Herndon, Fuel Recycle Division). The M-2 is an advanced servomanipulator for remote maintenance of components in industrial environments inaccessible to direct human entry.

ten years, ORNL has been developing the technology for reprocessing spent fuels, with major emphasis on the special problems of breeder fuels. The Laboratory has developed improved concepts and techniques that are recognized worldwide. It is leading the world in efforts to develop improved methods for remote maintenance in reprocessing facilities. Possibly of even greater importance, this remote technology can be applied to a wide variety of activities that must be carried out in hazardous environments (e.g., fusion, waste disposal, decommissioning, and cleanup of reactors and other nuclear facilities).

Since 1983 the primary program emphasis has been on initiating a major reprocessing equipment demonstration (cold) in the Integrated Equipment Test (IET) facility at ORNL. [A parallel effort to design a hot engineering test facility, the Breeder Reprocessing Engineering Test (BRET), has also been

under way; but recent DOE decisions have deferred the BRET until the overall breeder strategy has been redefined.] Component and operational testing and evaluation in the Remote Operation and Maintenance Demonstration and in the Integrated Process Demonstration portions of the IET facility continue.

With Hanford Engineering Development Laboratory, ORNL is leading a major collaborative strategy study to examine overall options and strategies for the fast reactor fuel cycle and to support innovative reactor design studies that DOE plans to initiate in FY 1985. The Secure Automated Fabrication facility and the proposed BRET facility located in the Fuels and Materials Examination Facility complex at Hanford are part of the study's evaluation. Expansion of their current capabilities is being investigated, and their potential role in the overall fuel cycle in support of the innovative reactor concepts will be examined.

ORNL will continue its active role in efforts to foster international collaboration and to examine the merits of cooperative fuel-cycle projects in the future. Exploratory discussions have taken place with France and the Federal Republic of Germany regarding their expressed interest in exchanges with the United States, activities under the United Kingdom exchange continue, and major new agreements are being developed with Japan for collaboration in experimental criticality work and in application of remote technology.

Nuclear Waste Management

ORNL nuclear waste management activity has both commercial and defense components. The commercial component, the Nuclear Waste Fund Program, addresses transportation of commercial nuclear wastes from point of generation to final isolation and their storage in geologic repositories. The defense component, the Defense Waste Management Program, addresses management of wastes generated at ORNL, development of technology for managing low-level radioactive wastes, and materials production involving administration of the national repository for ^{233}U and conversion of 100 kg of uranium from liquid to an inert solid.

The Program Management and Technical Support component of the Nuclear Waste Fund provides support for the Transportation Technology Center at Sandia National Laboratory (SNL) and major support for the Integrated Data Base (IDB) analysis, used by DOE in national waste management planning and analysis. The Repositories portion provides support for the continuation of the sensitivity and uncertainty analysis task for the Waste Isolation Program and for ORNL's new Sedimentary Rock Program, which will investigate the use of sedimentary rocks other than salts as hosts for a radioactive waste repository. In FY 1984 and FY 1985 the Sedimentary Rock Program will conduct literature-based geotechnical investigations and then recommend a list of the most promising sedimentary rocks to the Office of

Civilian Radioactive Waste Management (OCRWM). OCRWM's acceptance of the ORNL recommendation would initiate a formal site screening process, nomination of a site in the most promising rock by the end of FY 1988, and subsequently an in situ characterization of the site.

The major activities in the Defense Waste Program are the operations involved in managing radioactive waste generated at ORNL, decommissioning of surplus facilities, development of procedures and equipment to improve the safety and reliability of disposal operations, and participation in and management of the DOE Low-Level Waste Technology Program. The Defense Waste Management Program also provides major support for the IDB and supports a task for developing applications and uses for by-product radionuclides.

Hazardous Waste Management

ORNL is lead contractor for the Hazardous Chemical Defense Waste Management Program (HCDWMP) established in November 1983 to manage DOE hazardous and contaminated wastes (radioactive plus chemical). The goal of the program is to provide technology development to support ongoing generation, storage, and disposal of hazardous chemical wastes (HCWs) and mixed wastes such that public health and safety are protected and ecological impact is kept to a minimum. The central strategy of HCDWMP is completion of the technology development and demonstration needed to permit full compliance of all DOE facilities with the regulations governing hazardous waste generation, storage, and disposal and to expedite the application of currently available or newly developed technologies and engineering techniques.

Near-term components of this strategy involve defining the magnitude and character of HCW streams and inventories, the technology and facilities currently available to address them, and the regulatory and operational restraints on HCW management. This information will be

used to develop program plans and to recommend solutions to the identified problems. Over the longer term, an integrated, DOE-wide HCW management system will be implemented. Applied research for improved treatment and disposal options may also be continued.

Nuclear Power Systems for Space

One of the most critical components of a spacecraft is the power supply that provides electricity for its navigation, communication, and exploration instruments. While for short missions or missions that remain near the sun, storage batteries and fuel or solar cells are satisfactory, longer planetary explorations require systems that convert nuclear energy to electricity.

Because these nuclear-powered systems require special materials, ORNL is developing

and evaluating improved materials for space missions (and for terrestrial applications) that utilize heat generated by isotopic power devices. The Laboratory has produced iridium-alloy-cladding blanks to contain heat-generating isotopes as well as carbon-bonded carbon-fiber (CBCF) insulators that allow operating temperatures up to 1300°C. Other technology improvement activities have included (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 latitudes for the iridium alloy, (3) publication of an Isotope Space Power Materials Handbook, (4) nondestructive examination support for manufacture of advanced thermoelectric elements and the iridium alloy blanks, and (5) evaluation of measurements of the diffusivity and steady-state thermal conductivity of CBCF.

T. G. Hill, a technician in the Engineering Technology Division, adjusts the high-temperature multiaxial extensometer for measuring surfaces of constant inelastic strain-rate. This work supports the National Aeronautics and Space Administration effort to formulate mechanical behavior models for high-temperature structural alloys.

The Laboratory has assumed a lead role in the development and characterization of refractory alloys in the SP-100 Program on 100 KW(e) and multimewatt fission reactor concepts. The program is sponsored jointly by DOE, DOD, and NASA (National Aeronautics and Space Administration). An ORNL-designed system was selected as a reference concept in the formulation of a multiyear national technology development for multimewatt applications. It involves a direct potassium Rankine cycle reactor and flywheel storage for delivery in energy pulses of 1×10^4 MWs.

Light-Water Reactor Safety

ORNL light-water safety activities are undertaken for NRC. Through various NRC programs, the Laboratory provides research and technical support in areas where ORNL has proven expertise. These include structural analysis, materials evaluation, fission product behavior, accident sequence analysis, radiation dose and health effects, and advanced instrumentation development. NRC technical concerns derived from experience with operating nuclear reactors have resulted in many new and challenging ORNL programs. Included among these programs is work involving analyses of severe accident phenomena, operation and maintenance experience, operator-machine interactions, fission product release and transport, core-melt phenomena, long-term pressure-vessel behavior, risk assessment, and operating data.

The future direction of NRC programs is uncertain and difficult to determine because of the lack of new nuclear plant orders, the opportunities for regulatory reform, and the possible changes in the NRC research roles. ORNL is, however, actively pursuing the development of new programs concerned with the overall goal of improving nuclear plant safety. The increasing interest in extending the operational life of existing power plants beyond their original design is expected to result in increased research in aging characteristics of plant components. As experience accumulates, ORNL's program to evaluate

operating data will become more important. The human factors program will continue to provide increased understanding of the human component of risk. A unique experimental capability now being used in the Pressurized Thermal Shock Facility of the Heavy-Section Steel Technology Program provides confirmation of analytical predictions on behavior of thick-walled pressure vessels under combined thermal and pressure loadings.

Advanced Energy Systems Programs

Fusion

ORNL involvement in the effort to achieve controlled nuclear fission dates back to 1953, when a small theoretical study of possible approaches was conducted. Today the Laboratory's fusion program is a significant component of the U.S. national fusion program and encompasses nearly all aspects of magnetic fusion—theory, technology development, experimentation, planning, and coordination of industrial participation. The goal of the national fusion program is to determine whether the nuclear energy of the light elements, mainly hydrogen isotopes and lithium, can be released for useful purposes. Key issues at the current stage of the program are the understanding of the behavior of high-temperature hydrogen isotope plasmas; the development of magnetic configurations that confine plasma effectively and have attractive engineering features; the development of the technologies for producing, heating, and controlling such plasmas; the design of future confinement facilities; and the development of the technologies that will be required for magnetic fusion to move through the engineering phases into the commercial phase. The centerpiece of the future program in the next 15 years is a proposed deuterium-tritium burning tokamak designed for ignition.

The theoretical plasma physics program is continuing its development and application of

theories and models of plasma behavior in various confinement systems [in recent years, tokamak, stellarator, Elmo Bumpy Torus (EBT), and reverse field pinch]. This activity also encompasses the development of a data base for atomic physics and the development of diagnostic devices and technologies. In the tokamak and stellarator areas, ORNL will continue to develop theory—both for comparison with experiment and for predictive calculations—in magnetohydrodynamics, heat and particle transport, and heating and fueling. Studies of critical issues will be made for the Elmo Bumpy Square (EBS), and studies are planned on reactors, on advanced systems such as Advanced Toroidal Facility-2 (ATF-2), and on the ignited-plasma experiment.

In the atomic physics program, a powerful new source of multiply charged ions has been completed. 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, ORNL will develop a diagnostic device for measuring alpha particles.

Confinement Systems activities have traditionally included experiments and design studies in both the EBT and toroidal plasma configurations. Studies during 1983 and 1984 on the EBT-Scale experiment have led to a much better correspondence in detail of theory and experiment, while at the same time supporting a lower estimate of confinement capability than previously shown. The imaginative EBS configuration—which utilizes hot electron rings in bumpy straight sections combined with field corners and thus minimizes the effects of toroidal curvature on drift orbits—has been proposed as the new focus of this program. Unfortunately although the Magnetic Fusion Energy Advisory Committee found the EBS to be an exciting concept deserving of further

Tom Jernigan is shown with a model of the ORNL Advanced Toroidal Facility (ATF), which is designed to improve the fusion toroidal concept. The ATF is being built in the Fusion Energy Division and will begin operation in fall 1986.

support, national budget problems may preclude significant funding in FY 1985. To permit resubmission at a later date, work on updating the EBS proposal will continue.

In the toroidal area, the Impurity Study Experiment program has been completed. Major contributions in the final year included the study of Z-mode improvement to confinement at high beta, magnetohydrodynamics studies, plasma rotation and potential measurements (a collaboration with Rensselaer Polytechnic Institute), surface physics, diagnostics development, and pumped limiters. The device was closed down in late FY 1984 following a test of a beryllium limiter for the Joint European Torus project. Through 1986, the main part of the experimental group will be on assignment to the Princeton Plasma Physics Laboratory, where they will play a major role in the Tokamak Fusion Test Reactor (TFTR) program. Key personnel in the

expanding stellarator program will remain to work at the ATF project with Martin Marietta Energy Systems, Inc., engineering personnel. A device with outstanding capabilities, the ATF has the flexibility to study various magnetic configurations. Design and construction are proceeding on schedule, and the ATF will be available for operation in early FY 1987. A project is now being proposed that, after initial operation, will upgrade the ATF to operate in steady state with a high-performance plasma. The ATF will provide a major in-house focus for theory and experiment, diagnostics, and plasma technology.

The ORNL Development and Technology Program continues to make progress on all fronts. In the neutral beam area a prototype long-pulse source has been tested successfully. The Oak Ridge ion source was not chosen for future applications, and the program is being

Stan Milora (left) and Steve Combs of the Fusion Energy Division are shown with the latest version of an Oak Ridge National Laboratory pellet-fueling device for fusion research. These fueling systems have been developed at Oak Ridge and are now being applied to most major fusion experimental devices throughout the world.

substantially reduced as the ORNL Plasma Technology Section turns its attention increasingly to the development of rf (radio frequency) heating systems. An rf test facility, which utilizes the prototype EBT-P coils, is under construction and will be in operation in 1986. Development of rf systems is planned for D-III, ATF, TFTR, and the ignited plasma experiment. The pellet-injector program has developed both pneumatic and mechanical injectors capable of repetitively providing pellets at speeds of about 1 to 2 km/s. These injectors have been used recently in collaborative programs with the Massachusetts Institute of Technology on Alcator-C to produce record levels of the plasma confinement parameter and on the Princeton Large Torus. A very successful collaborative program has also been completed with an ORNL pellet device on D-III at GA Technologies. The next phases of the program will concentrate on higher velocity pellets leading to a tritium pellet injector for TFTR.

In the Large Coil Program, the Large Coil Test Facility has been completed, and five coils have been delivered. The first test has been completed using the Japanese coil, from Hitachi; the first U.S. coil, from General Dynamics; and the Swiss coil, from Brown-Boveri. The Euratom coil, built by Siemens, was recently installed in the facility, and the General Electric coil has been completed in the Oak Ridge Gaseous Diffusion Plant machine shop. All six coils, including one being fabricated by Westinghouse, will be in place and ready for testing during 1985. Testing will continue through 1987.

The Fusion Engineering Design Center (FEDC), which is managed by ORNL, involves substantial collaboration with a number of U.S. industries, national laboratories, universities, and foreign countries. The FEDC is a major contributor to the planning, design, and engineering of the burning core devices that are candidates for the next major focus of the U.S. Magnetic Fusion Program. The center also performs the engineering studies for the U.S. contribution to the International Atomic Energy Agency-International Tokamak Reactor activity. In addition, in collaboration with the Lawrence Livermore

National Laboratory LLNL), a significant effort is devoted to the next phase of the tandem mirror program. This work is expected to continue for a number of years, and it may well be extended to include supporting studies of other concepts.

In the program for an ignited plasma device, the Fusion Energy Program at the Laboratory has provided leadership in coordinating the R&D activities. Through this work, the FEDC effort, and support to other areas, the ignition experiment is expected to be an increasingly important part of the ORNL program.

Fossil

Since 1974 the Laboratory has conducted a significant program of R&D in fossil energy. Work is concentrated principally in the areas of environment and materials technology. Other areas of effort include process technology modeling, development, and assessment; process instrumentation; fuel supply modeling; and fossil energy information. The Laboratory has given emphasis to coal-related work, and the Fossil Energy Program provides the opportunity to integrate elements of work being carried out for the Assistant Secretary for Fossil Energy with that being done for various other parts of DOE (e.g., the Office of the Assistant Secretary for Policy, Safety, and Environment) and other federal organizations. The ORNL role in fossil energy also involves extensive interaction with industry and offers opportunities for cooperative efforts with individual companies working in the field.

Work in the ORNL Fossil Energy Program involves several areas of activity. Individual projects include work on computer modeling and simulation; evaluation of coal conversion technologies, including bioconversion concepts; and development of automated methods for analysis of coal liquids. The principal program emphasis, however, is on materials R&D and on environmental and health-related R&D. The materials R&D includes management (with ORO) of the National Fossil Energy Materials

Program and is directed toward development, joining, mechanical properties, corrosion and erosion, and wear of alloys; mechanical properties and corrosion of refractories; and powder synthesis, fabrication, characterization, and testing of ceramics. The environment and health R&D includes work within the Fossil Energy Technology Environment Program and is directed toward characterization and bioactivity assay of coal liquids, assessment of environmental control technology, treatment of coal conversion wastewaters and development of disposal methods for resulting sludges, characterization of fate and effects of coal liquids on aquatic and terrestrial organisms, industrial hygiene studies, disposal methods for solid wastes resulting from coal use, and improving current understanding of acid precipitation.

Conservation and Renewable Energy

ORNL research in energy conservation and renewables dates from 1971. In recent years the program has grown with the increasing national emphasis on these technologies.

ORNL has been assigned technical management responsibility for three programs in the buildings area: Building Thermal Envelope Systems and Materials (BTESM), Building Equipment Research (BER), and Residential Conservation Service (RCS). The BTESM program was initiated in response to the need of the insulation and building industries for relevant technical information on the thermal performance of building-envelope systems and in recognition of the impact that improved thermal performance of buildings would have on energy conservation. A National Program Plan—developed jointly, with the assistance of industry, by DOE, ORNL, and the National Bureau of Standards—forms the basis for selection of research projects. A highlight of the FY 1985 program will be the procurement of equipment to enable thorough testing of roofing segments. The level of effort is expected to increase during the plan-

ning period, with increased emphasis on roofing systems and retrofit research.

The BER program seeks to conserve energy by developing improved heating and cooling systems and appliances and by making better use of space-conditioning energy in buildings. Its activities include analytical studies, development of analytical tools, and laboratory and field experiments. The major BER program areas are nonazeotropic refrigerant mixtures, ground-coupled heat pumps, absorption, advanced insulation, vapor-compression systems, systems driven by Stirling engines, and heat pumps driven by internal combustion engines. The RCS program provides DOE with the technical management functions for effective implementation of the congressionally mandated retrofit program for buildings. As implementation activities are completed, the emphasis is shifting to program evaluation and research on improved retrofit techniques.

In the area of thermal energy storage, ORNL has responsibility for building heating and cooling applications and for industrial uses. Program objectives are to develop concepts for economical heat pump thermal storage, technologies for significantly increased reuse of high-temperature industrial reject heat, concepts for passive solar heat storage, a data base for new heat storage materials and processes, and effective interactions with the private sector to determine research needs and to transfer developed technologies. In battery storage, the Laboratory is investigating methods for increasing the conductivity and fracture toughness of sodium-alumina in support of the development of the sodium-sulfur battery.

ORNL Electric Energy Systems activities are concerned with power systems technology. Their purpose is to investigate new concepts and to develop future technologies for the electric utility industry. Project technologies offer opportunities to improve the efficiency of the electric energy system, both economically and through resource conservation. Activities are currently organized into eight major task areas: dielectrics, distribution automation and control, systems research, high-voltage alternating current, high-voltage

Don Waiukas (left) and Phil Childs of the Energy Division take measurements of roof test samples on the Roof Thermal Research Apparatus.

direct current, materials, electromagnetic pulse, and electric fields. Significant accomplishments during FY 1984 include determination of the properties of solid polymer insulators, continued development of fine-grained zinc oxide varistors, development of ductile amorphous metals, and development of a risk assessment methodology for 60-Hz high-voltage transmission lines. In the future, tasks related to high-voltage direct current, dielectrics, electromagnetic pulse, and distribution automation will be emphasized, while work in systems research and high-voltage alternating current will be deemphasized. A major project for the next few years will be the Athens Automation and Control Experiment. A large-scale distribution automation and control project being installed on the Athens, Tennessee, Utilities Board electricity distribution system, its purpose is to test load control on an actual utility system and to transfer what is learned to the electric utility industry.

ORNL is responsible for two projects in industrial conservation: Materials for Waste

Heat Utilization and Chemical Heat Pumps. The first provides materials technology support to DOE and its contractors in support of recuperator and improved ceramic technologies development. The second develops chemical heat pump technology for recovering industrial and process waste heat, and during FY 1984 it completed a comprehensive evaluation of potential chemical heat pump technologies.

Activities in transportation research include 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 Programs. The ceramic technology program is expected to receive substantial increases in operating support during the next four years; and in accord with the program plan, activities will include determining the mechanisms controlling reliability, improving processes for fabricating ceramics, and testing ceramic materials in simulated engine environments to confirm reliability. A new facility for the Office of Vehicle

and Engine Research, the High Temperature Materials Laboratory (HTML), is scheduled for completion and occupancy in FY 1987. It will house laboratories and unique special equipment for high-temperature materials research by ORNL staff and by researchers from industry, universities, and other government laboratories.

In Multisector activities, ORNL has been assigned technical management responsibility for the Materials Project and participates in the Tribology Project—both in the Energy Conversion and Utilization Technologies program. Under the Materials Project, research is being conducted on high-temperature materials, lightweight materials, and materials properties modeling. Under the Tribology Project, the principal work element is friction and wear of ceramics. Substantial increases in activity are expected for the Materials Project during the next two years as a result of the large number of successful developments by ORNL and several subcontractors. Two additional Multisector projects are the development of microemulsion fuels and the evaluation of results obtained through the Energy Related Inventions Program. A new research project in biocatalysis development will be initiated in FY 1985.

The principal activity in solar energy is the technical management of the Biomass Production Program, which consists of long-term research on the production of woody and herbaceous biomass, biofuels multiyear program planning, and environmental and economic assessment. ORNL will continue research on herbaceous crop resources, environmental effects, and long-term productivity and economics; complementary research on woody crops; and development of multiyear program plans. The program planning task is carried out through collaboration with the other laboratory biomass field managers at Argonne National Laboratory (ANL), Pacific Northwest Laboratory (PNL), and the Solar Energy Research Institute.

Laboratory participation in other solar programs is limited to tasks in which specific expertise is available, including technical assistance on photovoltaic projects, environmental analysis for alcohol fuels, and analysis of wind energy systems.

Finally, ORNL performs small amounts of work in the geothermal and hydropower areas. In geothermal, researchers examine proposed installations to ensure that the associated environmental impacts are within acceptable limits. In hydropower, ORNL provides technical assistance to DOE for resolution of specific environmental issues associated with small hydropower development. In FY 1985 the program will monitor subcontract research on fish mortality related to turbines and complete instream flow research.

Social Sciences

Most of the social science research at ORNL is done by people in the Energy Division of Advanced Energy Systems. The need for social science research derives from the fact that most energy issues are not merely technological but also involve strong social, economic, and political aspects. Problem solving requires research on all aspects, and ORNL has evolved a unique setting and collection of talent that encourages addressing problems comprehensively.

Consequently social scientists are involved in a wide variety of applied topics, most of which require multidisciplinary teams. Areas of research include: analyzing socioeconomic impacts of energy technologies, especially in connection with environmental impact statements; studying the conditions of acceptability of technological options such as different approaches for handling toxic materials; helping DOD develop transportation routing models for logistics planning; planning emergency responses for DOE; studying the economics of postdisaster recovery for the Federal Emergency Management Agency; improving technology transfer; helping the Agency for International Development provide developing nations with energy planning support; developing energy demand models to forecast the effects of new technologies and policies; evaluating the effectiveness of government and utility energy conservation programs; analyzing the economics of plantations for biomass fuel; analyzing the fuel savings-

equipment cost trade-off and the market for diesel cars; and estimating the economics of reactor decommissioning as influenced by various regulatory policies.

Basic Physical Sciences Programs

Nuclear and High-Energy Physics

The principal activities of the ORNL Nuclear Physics Program are centered on the HHIRF, which is operated as a unique resource for heavy-ion research for national user communities and which serves as the basis of a vigorous in-house nuclear physics research program. In FY 1984, more than 120 researchers from 40 outside institutions participated in HHIRF experiments. The Nuclear Physics Program also supports efforts in nuclear theory, light-ion nuclear physics, and resonance neutron capture studies and provides assistance to the Continuous Electron Beam Accelerator Facility project. To increase utilization of the HHIRF, a modest increase in funding has been proposed beginning in FY 1986.

The dedication of The University of Tennessee-Vanderbilt-ORNL Joint Center for Heavy Ion Research at HHIRF in 1984 ushered in a new era in federal, state, and private sector cooperation in research. A new research trend that began in FY 1984 is an experimental effort in relativistic heavy-ion physics. ORNL staff involved in this experimental program will participate in research at the PS/SPS accelerators at the European Organization for Nuclear Research and the AGS accelerator at Brookhaven National Laboratory (BNL). A companion effort begun the same year is developing criteria and design for a relativistic heavy-ion collider, which would be a major construction addition to the HHIRF. This facility, for which construction would be timed to begin toward the end of the planning period

(FY 1989 to FY 1990), would provide ion energies to 10 GeV/A.

The High Energy Physics group provides an essential service to the physics community by measuring and calculating multigroup cross sections and transport phenomena for a wide variety of applications. Nuclear cross-section models and nucleon-meson transport methods are developed that facilitate the design of high-energy particle detection systems, such as ionization calorimeters and total absorption calorimeters. Design data as well as detailed designs are provided to outside experimental groups engaged in detector construction, and a parallel effort provides information required for meeting radiation shielding requirements. These ORNL activities are projected to continue, with increased collaboration with southeastern universities. Experimental high-energy physics research is also expected to continue in collaboration with The University of Tennessee.

Nuclear Sciences

The four major components of ORNL work in the Nuclear Sciences subprogram are nuclear data measurements with the Oak Ridge Electron Accelerator, research in heavy-element chemistry, electromagnetic isotope separation using the calutrons, and special isotope production at the High Flux Isotope Reactor (HFIR) and transuranium (TRU) element processing at the TRU facility. The combination of the HFIR and TRU facilities represents a unique source of isotopes for transplutonium research in the free world. HFIR-TRU production of the isotope ^{254}Es , and subsequent research in the chemistry of transeinsteinium elements, is expected to be an increasingly important activity. This includes a new multilaboratory initiative, the Large Einsteinium Activation Project, which has been proposed by ORNL, LLNL, Lawrence Berkeley Laboratory, and Los Alamos National Laboratory. The participants would use ^{254}Es from the HFIR-TRU for research on the chemistry and nuclear physics of transeinsteinium elements and in the search for new superheavy elements. Isotopes separated in the ORNL calutrons will

continue to be essential to a wide spectrum of research activities and to the production of a variety of radiopharmaceuticals.

Materials Sciences

Research sponsored by the Materials Sciences subprogram provides a deeper understanding of the properties of materials and develops new materials of potential benefit to the energy tech-

nologies. A variety of techniques—including electron microscopy; neutron, X-ray, and electron scattering; ion bombardment; and laser processing—are employed to characterize materials and to identify specific physical properties that govern, for example, corrosion, radiation, superconductivity, fracture resistance, toughness, and photovoltaic conversion efficiency. The understanding gained is used to design materials and processing techniques in order to achieve more desirable properties.

Operations Division personnel are shown in the control room at the Electromagnetic Isotope Enrichment Facility, where isotopes are separated for uses such as medical health care delivery and research in biology, biomedicine, geology, nuclear chemistry, and nuclear physics.

At the Surface Modification and Characterization Laboratory, Steve Withrow (left) and Bob Culbertson of the Solid State Division use ion scattering to investigate the structure of single-crystal surfaces.

Theoretical studies proceed in parallel with experimental research. Increased emphasis and growth are projected through 1990 in several key areas: research on new alloys and toughened ceramics at the HTML and on neutron scattering at the HFIR, and studies of neutron-induced defects at the National Low Temperature Irradiation Facility now under construction and on surface modification using ion beams and laser processing at the Surface Modification and Characterization Center. An imaging atom probe under construction will provide significant new capabilities to several activities in these areas. The design and construction of instrumentation for radiation damage and neutron scattering research at HFIR-II, discussed in New Initiatives, are projected to become increasingly important activities in the latter part of the 1980s. In addition, increased utilization of synchrotron radiation for surface and materials research is envisioned.

Chemical Sciences

The Chemical Sciences subprogram supports research in chemical physics, atomic physics, chemical energy, separations and analysis, and chemical engineering. Activities include studies of chemical processes at the high pressures and temperatures encountered in energy conversion facilities; of fuel cycle chemistry, the chemistry of improved extractants for the separation of metals from solutions; and of coal structure and reactivity. Studies of high-energy atomic collisions are conducted using the EN and HHIRF tandem accelerator facilities. The development of improved techniques involving microwaves, positron beams, electron spectroscopy, optoacoustic phenomena, mass spectrometry, and laser methods receives considerable emphasis.

The proposed construction of the Analytical Mass Spectrometry Laboratory at ORNL would permit relocation of this program's sophisticated

Warren Sisson of the Chemical Technology Division makes focus refinements to a high-speed video camera. The camera is used to monitor the behavior of droplets being formed in an electric field in liquid-liquid systems.

N. A. Teasley (left) of the Analytical Chemistry Division and R. Fell, a consultant from Virginia Polytechnic Institute and State University, prepare radioactive tracer material for determining transport parameters of honeybees in a flight chamber.

spectrometers from their current location at the Y-12 site, rendering them much more accessible to other activities supported by Chemical Sciences. The move undoubtedly would enhance the effectiveness of all related research. Increased emphasis and growth are planned for research on the role of molecular bonding and structure in determining kinetic, equilibrium, and interfacial behavior of solvent-extraction systems. Growth is also projected in the study of multiphase transport phenomena and in the investigation of the role of atmospheric chemistry in acid deposition.

Engineering, Mathematics, and Geosciences

Work in the Engineering, Mathematics, and Geosciences subprograms includes the development of new mathematical and statistical methods of analysis, studies of geochemical processes that promote transportation and redistribution of materials in the earth's crust, and research aimed at developing control technology for large complex engineering systems. The latter work is carried out at the ORNL Center for Engineering Systems Advanced Research, for

Deanna Barnett, a co-op student in computer science from The University of Tennessee at Chattanooga, and Tom Swift, an electrical engineering graduate student at The University of Tennessee at Knoxville, are shown with the prototype mobile robot HERMIES-1 (Hostile Environment Robotic Machine Intelligence Experiment: Series 1) at the Oak Ridge National Laboratory Center for Engineering Systems Advanced Research in the Engineering Physics and Mathematics Division.

which significant growth is projected in the development and understanding of intelligent machines. In the mathematics area, the development of new algorithms that exploit advances in parallel processor architectures will receive emphasis.

Biomedical and Environmental Sciences Programs

Basic Biological and Biomedical Research

ORNL basic biological and biomedical research is largely devoted to studying the effects of energy-related chemical and physical agents at the molecular, cellular, and whole-animal levels. Strong emphasis is also placed on the production, development, and use of materials that ultimately function as radiopharmaceuticals. Laboratory research efforts in protein engineering, described in New Initiatives, have accelerated.

Molecular studies of potentially hazardous agents include efforts to characterize their fundamental physical and chemical properties, to ascertain their mechanisms of interaction with metabolic pathways in biological systems, and to determine alterations of their effects by natural biological repair mechanisms. Study of the functions of proteins and nucleic acids is crucial to the understanding of the response of biological systems to environmental stresses such as ultraviolet and ionizing radiation, chemical pollutants, and toxic compounds. ORNL researchers continue to investigate the correlation of protein structure with function and to study the mechanisms of deoxyribonucleic acid (DNA) replication and protein synthesis. High priority is given to research on mechanisms of radiation lethality, chromosome chemistry, gene expressions in carcinogenesis, carcinogen-cell genome interactions, and tumor cell immunology. Assay systems are used to test the potential hazards of

chemical and physical agents in such organisms as bacteria, viruses, fruit flies, mice, and many types of human and animal cells in culture.

The study of carcinogenesis, mutagenesis, and other forms of damage to biological systems is particularly vital in health effects research. In the Laboratory carcinogenesis research program, high priority is given to radiation biology, particularly fission neutron and gamma-ray effects; time-dose relationships in radiation carcinogenesis; dose-response relationships in chemical carcinogenesis; bioassay carcinogenesis; and carcinogenic activity in human cells. The mutagenesis research program emphasizes mammalian chemical mutagenesis, genetic effects of plutonium, metabolism of mutagens, and basic research into the genetic basis of mutagenesis.

ORNL work in experimental genetics, the main theme of Laboratory biological research, will continue to elucidate the nature of genetic materials at the molecular, genomic, and chromosomal levels of organization and to learn how gene expression is controlled in health and disease. At the molecular level, the accelerated effort in protein engineering combines the expertise of molecular biologists and biochemists to focus on a promising field of research made possible by technological advances in genetic engineering. At the level of the whole animal, the research will continue to concentrate on the mouse, the only mammal besides human beings for which sufficient background knowledge exists for meaningful genetics research. This research takes advantage of a unique and invaluable resource at ORNL, a collection of 200,000 genetically defined mice—the only federal resource of this sort in existence. Other research efforts in biology share overlapping interests with genetics research, thus promoting interdisciplinary collaboration.

In addition to DOE support for such studies, ORNL also receives substantial funding from DHHS. The Laboratory expects an expanded effort in radiation carcinogenesis research supported by the National Cancer Institute. For the Food and Drug Administration, the National Library of Medicine, and the National Toxicology Program, ORNL is developing nationally

To measure the effects of radiation and chemical substances in the genetic material in cells, H. E. Luippold (left) and R. J. Preston of the Biology Division examine chromosomes from the cells in human blood.

and internationally available data bases in the areas of genetic, reproductive, and general toxicology.

The ORNL Nuclear Medicine Program has received widespread recognition for the design, synthesis, and animal testing of new radiopharmaceuticals for use in clinical nuclear medicine and other radiolabeled agents for fundamental biomedical research. A major effort in the 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 program is complemented by an active extramural collaborative effort through cooperative programs with medical institutions such as Massachusetts General Hospital and Boston's Children's Hospital.

Basic Ecological Research

The primary objectives of ORNL's environmental research are to determine the fundamental processes and pathways by which contaminants move through the environment, including source, form, and potential concentrations received by human beings; to determine mechanisms by which the environment modifies contaminants, either decreasing or increasing potential hazards; and to identify potential ecological effects that may result from exploitation or production of various energy sources. The understanding of environmental processes developed in basic ecological research is essential in meeting these objectives. Research on the

mechanisms that govern ecosystem function, particularly in biochemical cycling studies on forested landscapes and in southeastern reservoirs, is particularly valuable; by using process studies with stable elements, radionuclides, and trace organics as well as mathematical simulation models, ORNL develops data and methodologies that enhance the ability to site and operate energy systems in a cost-effective and environmentally safe manner. In support of the developing DOE programs in subsurface transport of hazardous substances, ORNL will also continue to expand its expertise in hydrology and geochemistry.

In addition to DOE support for basic ecological research, NSF also provides funding. NSF supports the study of material spiraling in stream ecosystems as an approach for the analysis of the transport and retention of nutrients and organic matter, for the study of the role of the terrestrial biosphere in the global carbon cycle, and for the development and application of new methodologies for analyzing ecosystem problems. For EPA, ORNL has initiated new research in environmental toxicology to evaluate the utility of aquatic ecosystem models for predicting the ecological effects of toxicants.

Environmental Impact Assessment

Environmental impact assessment is a well-established activity at ORNL. Since 1971, Laboratory researchers have been preparing environmental impact statements on a variety of projects, including nuclear power plants; enhanced oil recovery; solar energy (photovoltaic and biomass); geothermal energy; coal gasification and liquefaction; uranium mining, milling, and enrichment; fusion; waste isolation; and such legislative actions as the Fuel Use Act and the National Energy Plan. In FY 1985 ORNL impact assessment staff are expected to provide increased environmental technical assistance to the Office of Environmental Compliance, which has the responsibility to ensure that all DOE

activities are in compliance with the National Environmental Protection Act (NEPA) and other environmental laws and regulations.

ORNL will continue NEPA support and develop a system for tracking and analyzing DOE federal regulatory initiatives. For seven years the Laboratory has supported the DOE Office of Environmental Analysis in energy resource assessment models and in the provision of background research for various energy policy issues. This support will continue, with increased attention to acidic deposition issues. The sponsors of the Emergency Technology Program (ETP) plan to increase the research component of the program.

Under ETP, ORNL personnel review and assist in emergency planning and preparedness for environmental protection and public safety. ORNL also supports the DOE role in emergency test exercises and various emergency preparedness issues by conducting assessments of industry vulnerability to emergencies and by providing technical assistance in policy and evaluation.

Health and Environmental Risk Assessment

Assessments of potential health and environmental risks associated with new and existing energy technologies require knowledge of the interaction of potentially hazardous agents with biological and environmental systems and the technical capability for characterizing and quantitatively measuring such agents in various settings. ORNL studies involve the structures and properties of materials of biological or environmental importance, the physical and chemical mechanisms that govern transport and chemical transformations of pollutants in the atmosphere-hydrosphere-biosphere, and the details of direct interactions of harmful agents with biological materials. The scope of the work includes theoretical and experimental studies of interactions at the atomic, molecular, and macroscopic levels in solids and gases and on

solid surfaces and solid-liquid interfaces. Monte Carlo studies are made of the physical and chemical evolution of radiation-induced products in natural media.

The Laboratory gives strong emphasis to developing techniques that provide advanced instrumentation for characterizing and sensitively detecting a wide variety of chemical species. Included in this effort are unique applications of laser optical techniques, ultraviolet and soft X-ray spectroscopic techniques, and electron-beam microlithography. A continuing research activity, which is funded by the DOE Office of Health and Environmental Research (OHER) but which has resulted in support from other agencies and organizations for applied studies, is the development of new instruments and measurement techniques to support evaluation of the potential health and environmental impact of developing energy technologies. Results of this research have led to

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. Transfer of this technology to the commercial sector is an important objective.

Because many of the energy-related materials of potential importance for human health are mixtures of chemicals rather than single substances, OHER has implemented a new initiative to elucidate the mechanisms of interaction between compounds in complex mixtures. ORNL has the lead role in the investigation of adverse health effects that can be attributed to model compounds within mixtures. Research emphasis at the Laboratory is therefore shifting from evaluating the toxic effects of mixtures on experimental animals to the investigation of hypotheses about the inhibition or enhancement of toxicologic effects of chemical substances when they are components of mixtures. These

C. H. Chen (left) and S. D. Kramer of the Health and Safety Research Division use the light from four pulsed lasers to selectively excite and ionize atoms of the rare gases krypton, argon, and xenon in the counting chamber. This procedure can be used to date groundwater and polar ice up to about 1 million years.

studies will provide a rational basis for assessing potential health risks from exposure to complex mixtures.

Much of ORNL's work for EPA also provides methods development for risk analysis and determination of detriment or risk from potentially hazardous materials. Though data base development activities decreased in 1983 and 1984, significant portions of the Environmental Mutagens, Teratogens, and Carcinogens data base development will continue in support of programs for the EPA Office of Toxic Substances.

Global Environmental Concerns

In the area of global environmental concerns, ORNL has become a center of expertise in the investigation of ecological transport and effects and in the assessment of acid deposition. The Laboratory proposes to expand its research efforts to encompass the role of terrestrial-aquatic linkages 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. ORNL is doing research for OHER on biogeochemical cycling in Walker Branch Watershed and on hydrologic transport of trace elements in contrasting watersheds. An important research and modeling center for OER in the global carbon cycle, ORNL also provides support for program planning and evaluation. In collaboration with ANL, BNL, and PNL, the Laboratory has proposed testing a conceptual model of surface water acidification and recovery for a forested watershed. The two approaches would be (1) to demonstrate the extent and rates of integrated watershed responses, given certain ecosystems characteristics and differing levels of atmospheric deposition of acidity, and (2) to test under what conditions and at what rates the individual steps involved lead to the modeled effects. Test results would be used to parameterize watershed-level

models for testing integrated watershed responses.

ORNL acidic precipitation research activities for EPA are increasing. Major research emphases are integrated assessment support to the National Acidic Precipitation Assessment Program and the effects of acidic precipitation on agricultural and natural systems and on ion mobility in soils. ORNL also has a lead role for EPA in planning and organizing the research in the Terrestrial Effects of Acidic Precipitation Program.

During the next five years, the global carbon cycling program activities will encompass new research in terrestrial carbon dynamics and global carbon cycle modeling, as well as new responsibilities in carbon cycle research management for DOE. Research efforts will focus on assembling and implementing disaggregated (multidimensional) models of the global carbon cycle. Management activities will involve the gradual assimilation of a greater share of contract execution activities for the DOE Carbon Cycle Research Program, particularly in the areas of oceanic data collection and analysis. This broad array of activities and expertise is necessary for developing the information and models needed to provide accurate projections of carbon dioxide (CO₂) buildup in the atmosphere over the next century from both natural and anthropogenic sources.

The Carbon Dioxide Information Center (CDIC) supports the nation's CO₂ research program and cooperates in information exchange with the international scientific community by addressing global atmospheric CO₂ problems. CDIC's objective is to provide a focal point for the compilation and distribution of CO₂ related information under systematic quality control; and its 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. In addition to its information dissemination function, CDIC participates in R&D activities, an effort required by the national CO₂ research program.

Strategic Planning

Planning is conducted at all levels of ORNL. The major planning activities include

- The Institutional Plan—a Laboratory-wide plan prepared each year
- Divisional and Program Plans—five-year plans prepared every three years by major programs and by all research divisions
- Site and Facilities Plan—a periodic plan covering physical resources
- Computing Plan—the ORNL component of Energy Systems' annual plan for computing resources

Computer planning is a new element of ORNL's strategic planning activities. It is one of the Laboratory's most visible plans.

The 1980s promise to be the decade of the computer. The much publicized advent of the personal or microcomputer has opened up new ways of using a computer and has caused more people to view it as a tool they can use effectively in their own work. Large centralized computers allow data to be easily shared between

users, and they offer the speed and power necessary to solve many important scientific and engineering problems. Recent advances in microelectronics and software present excellent opportunities to increase productivity. In many areas of science and technology, access to state-of-the-art computing facilities has become a prerequisite for performing world class research. To a large and diversified laboratory like ORNL, these computing advances are especially important.

Planning in computing, however, is difficult; technology is developing rapidly, and it is extremely diverse. At present ORNL is preparing a Long-Range Plan for its computing activities. One objective of this plan will be to take the maximum advantage of opportunities provided by computers for increasing productivity. A second objective will be to provide the technical and scientific staff access to the powerful machines they need for solving problems related to energy development. Proper planning will require input from many ORNL staff members concerning the computing needs of the program on which they work.

New Initiatives

The new initiatives represent research activities and directions that senior Laboratory management feels are consistent with the role of Oak Ridge National Laboratory (ORNL). Portions of three of these new initiatives have received funding through the Director's Research and Development (R&D) Fund, a source of internal support for the initiation and early investigations of projects considered by senior management to be appropriate new directions for Laboratory R&D.

Expanded Role for ORNL in an Ignited-Plasma Fusion Experiment

A tokamak ignition device is being considered by the Department of Energy (DOE) Office of Fusion Energy as the next major focus for the Magnetic Fusion Program. The main goal of this device, which has also been called a burning core experiment, is the production of ignited, long-pulse, deuterium-tritium burning plasmas. If 300-s pulses are successfully achieved, the feasibility of fusion power as a net energy generator will be demonstrated. In preconceptual design studies, two main configurations are being considered. The first of these has superconducting coils with a major radius of about 3.5 m, a plasma current of 7-11 MA, a toroidal magnetic field of 5 T, and a minimum integrated burn time of 2×10^5 burn-seconds. The maximum tritium inventory will be <200 g, and the vulnerable tritium inventory will be <18 g. Facility requirements include the need to handle tritium, to provide an exclusion zone for the site, and to provide up to a few hundred megawatts of electrical power and an average cooling of approximately 50 MW(th)

for the basic machine. Possible upgrades to greater performance are being studied. The second configuration uses water-cooled copper coils, and studies are under way to identify the lowest cost, smallest ignition machine by this route.

There are two complementary roles for ORNL in an ignited-plasma experiment. The first of these, discussed below, is independent of the siting of the device. The second involves the possibility of the Oak Ridge area as a site.

ORNL and the Engineering and Computing and Telecommunications divisions are actively involved in the project to study specific machine concepts, both through the Fusion Engineering Design Center (FEDC) and through the Fusion Energy Division. The FEDC gives support in plasma engineering, engineering, and systems integration to this program. Through the Fusion Energy Division, ORNL has been responsible for coordinating the R&D needs assessment for the project team. Plans are being formulated to expand the role of ORNL in the project and in the overall program. This may be accomplished through increased support of the FEDC; independent studies, in cooperation with other laboratories, of critical issues such as noninductive current drive and particle and impurity control; increased effort on one of the contending designs; and increased development and technology support. All of these efforts should enhance the role of the FEDC and ORNL in building the project if it is authorized.

In the early phase of the program, fusion planners assumed that an ignited-plasma device would be built at Princeton Plasma Physics Laboratory (PPPL)—because the effort was considered a continuation of the Tokamak Reactor (TFTR) program and because using TFTR facilities would minimize the cost. This assumption has now been questioned, notably in a 1983 report by the Energy Research Advisory

Board. Questions have been raised about limitations the PPPL site might impose on the larger device and its upgrades, and the likelihood that subsequent more powerful devices could not be sited there. While the TFTR site may be the logical choice for a small ignition device, the Oak Ridge Reservation offers superior capability for the larger experiment and for future fusion projects. A siting document has been drafted that outlines the capabilities of ORNL, the Oak Ridge Gaseous Diffusion Plant (ORGDP), and the facilities available for the Poplar Creek site. Located adjacent to ORGDP, the site has available over 1000 MW(e) of electrical switchyards and hundreds of megawatts (thermal) of cooling. It is near available office, storage, and support facilities including a large machine shop. The site is compatible with many times the tritium requirements of an ignited-plasma experiment, and it is readily accessible by road, rail, and river. If locations other than Princeton are considered, ORNL proposes to extend and complete these preliminary studies and to promote actively the Oak Ridge area as the site for the experiment.

The cost of the larger device and its supporting activities is about \$1 billion, and when completed it would entail upward of \$100 million in annual operating costs. The project would be a collaborative venture involving industry, universities, national laboratories, and possibly other countries. Because of its size and the need for fully integrated project management, a separate organization, parallel to ORNL, would be formed as a part of Martin Marietta Energy Systems, Inc.

New Concepts in Research Reactors: HFIR-II

ORNL proposes to design and construct the world's best research reactor as a replacement for the High Flux Isotope Reactor (HFIR). The three major goals of the project are (1) to provide unsurpassed neutron scattering facilities for the growing community of scientists engaged in

using the neutron as a probe to study the structure and dynamics of materials; (2) to improve the nation's isotope production capabilities; and (3) to provide improved, flexible facilities for materials irradiation studies.

Neutron scattering, which was born as a by-product of the U.S. investment in research reactors, has provided unique and fundamentally important information for a wide variety of scientific disciplines: condensed matter physics, chemistry, biology, materials science, and polymer science. In recent years, because of a much larger investment in funds and personnel by the West Europeans, the United States has lost the role of world leadership in neutron scattering. The time has come to leap ahead in this field by replacing some of America's aging neutron sources currently in use by new, more powerful facilities. The benefits to neutron scattering will come in part from a higher thermal flux and in part from the opportunity to build better beam tubes, to add cold neutron sources, and to build more and improved scattering instruments. By combining higher source strength and improved beam tube design, the Laboratory plans to achieve an order of magnitude increase in the number of neutrons incident on the sample for many experiments. The planned cold sources and beam guides should provide cold neutron beams six times as intense as those at the Institut Laue-Langevin.

The HFIR was designed to produce a very high flux of thermal neutrons in the central flux-trap region for the production of transuranium elements. The chemistry of these elements and their compounds constitutes one of the most challenging and significant frontiers of the chemical sciences. The production of certain important isotopes, such as ^{252}Ca and ^{254}Es , would be enhanced by a factor of 1.5 by providing a neutron spectrum that has more epithermal neutrons than are available in the HFIR. The new design will provide target positions in various locations within the central region and the outer reflector to allow isotope production with differing neutron spectra. The epithermal flux is expected to be at least a factor of 3 higher than that in the HFIR.

The most difficult materials problem that the United States faces is in the construction of fusion reactors. A new research reactor with improved irradiation facilities and abundant fast neutrons would be a major resource for the fusion materials program, and the demise of the Fusion Materials Irradiation Test Facility gives the subject even greater importance. By providing target positions close to the reactor core and providing for control and monitoring of the sample environment, ORNL will greatly improve its capabilities for irradiation effects experiments.

Neutron scattering is a field ideally suited for the establishment of a strong user program at a national laboratory. It requires a large, expensive facility and has important applications in many scientific disciplines. The total number of neutron scattering users at all U.S. facilities has increased from about 250 to over 500 in the last 5 years. American industry is now becoming aware of the value of neutron scattering for understanding the behavior of new materials. In the past 3 years, 23 scientists from companies such as Eastman Kodak, Firestone, E. I. Du Pont de Nemours, Exxon, IBM, Ford, and Chevron have used the neutron scattering facilities at the HFIR. The proposed reactor would be operated as a national user facility, open to any research proposal of high scientific merit.

Preconceptual design studies are already in progress. The proposed reactor will be designed for approximately 200 MW of thermal power, with a large deuterium oxide (D_2O) reflector to accommodate many experimental facilities. The fuel will probably have cylindrical symmetry, with the exact geometry selected to maximize the utilization of the neutron flux. Preliminary calculations indicate that a peak thermal flux in the reflector of about $5 \times 10^{15} \text{ n}/(\text{cm}^2 \cdot \text{s})$ can be achieved with only modest advances in current technology. To provide neutrons over a wide range of energies for scattering experiments, two cold sources and a hot source will be installed in the D_2O reflector. Totally reflecting guides will conduct the cold neutrons to a large guide hall adjacent to the reactor building. Sufficient beam tubes and beam guides will be provided to allow the installation of about 30 neutron spec-

trometers of various types. The mix of spectrometer types will be decided after consultation with prospective users in the fields of solid state physics, metallurgy, biology, chemistry, polymer science, and nuclear physics.

Advanced Reactor Program

The cancellation of the Clinch River Breeder Reactor Project forces the United States into a reconsideration of the course of federally supported reactor development and demonstration. The future of the breeder must be considered in context with the problems in the commercial reactor industry and the recent increase in interest in small reactors, demonstrably safe reactors, advanced convertor reactors, and reactors for military applications. Having both breadth and depth in reactor R&D and broad multidisciplinary capabilities, ORNL is superbly equipped to provide both leadership and support to DOE in the evolving reactor programs.

The first step in the restructuring of the U.S. reactor programs is the definition of goals and objectives. The next step is the examination of specific and generic technological issues and options for the future of nuclear power. ORNL has instituted a discretionary-funded effort to initiate work in these first two steps. The study effort includes broad contacts with industry, government, and a senior advisory committee. This work will serve well as a planning and evaluation service to the national programs.

As the advanced reactor program evolves to provide technology to meet future needs, ORNL will support DOE through analyses to determine priorities for technology initiatives. Analyses and experiments will be carried out in the base technology areas currently addressed in the ORNL program: safety, shielding, materials and structures, and instrumentation and controls.

The materials and structures program will contribute in the following important areas: (1) removal of anticipated licensing impediments through confirmatory structural design testing programs, generation of mechanical properties for castings and weldment, evaluation

of irradiation effects, in-service inspection of stainless steel weldments, and high-temperature fracture mechanics; (2) qualification of modified 9 Cr-1 Mo steel as the universal liquid-metal reactor system alloy with the best possibility of eliminating not only the transition joints but also the intermediate heat transport system; (3) development of improved inelastic design guidelines and procedures; (4) reform of design codes and standards and engineering practices, which will lead to simpler, less conservative rules and simplified design analysis methods; and (5) incorporation of information from foreign programs through exchange and collaboration.

In the area of safety, increased emphasis will be placed on experimental validation of intrinsic shutdown heat removal for specific innovative designs. The shielding effort will concentrate on providing shielding analysis and on qualifying advanced shielding materials such as boron carbide and boronated graphites. Advanced instrument components, methods, and systems will be developed and qualified for commercial innovative plant design, including automated control system designs. Advanced computer technology such as artificial intelligence will be applied to reactor design, construction, operation, and maintenance.

In summary, ORNL will assume a lead support role to DOE in the development and evaluation of advanced reactor concepts and designs. This will include base technology support, system studies, design analysis, and evaluation. The overall objective of this effort is (1) economic competitiveness with conventional light-water reactors (LWRs) and fossil plants, (2) the capability of being fabricated and constructed within five years, (3) substantially reduced complexity compared with conventional LWRs, (4) environmental acceptability, and (5) a breeder option with an acceptable growth.

Strategic National Defense System

ORNL has extensive experience in many of the technology areas closely related to some of

the mission requirements being considered in the Strategic Defense Initiative of the Department of Defense (DOD). For example, ORNL has prepared a preliminary design of a space-based, multimewatt power system with an integrated flywheel storage system capable of delivering 1×10^4 MWs of pulsed energy; this is equivalent to the amount of electricity used by the city of Oak Ridge in 1 h. The power and energy storage systems are designed for delivery to orbit as two space shuttle payloads. Also, neutral-beam research at ORNL has resulted in the development of negative particle sources having extremely low beam-divergence. The divergence is so low that a beam launched in Oak Ridge would pass through an office doorway in Princeton, New Jersey, if the particle accelerator introduced no further spread. These sources can help provide the high-intensity, tightly collimated beam needed for directed energy applications.

The work proposed in this initiative will utilize and build on technologies and experience well established at ORNL. Relevant space reactor background at ORNL includes the Medium Power Reactor Experiment program conducted in the 1960s and the extensive high-temperature, liquid-metal-cooled component and system development activities. The technology base established in the recent Mechanical Energy Storage program and by other major technology development programs being carried out at other installations in the Oak Ridge area provides strong background for the proposed energy storage system. The beam technology required is supported by a large body of ion-source development work carried out over the last two decades.

The ORNL mission, in cooperation with other DOE and DOD laboratories and industry, will be to evaluate and develop the system concept, plan the technology development program, implement those parts appropriate to Oak Ridge expertise, and coordinate the remaining work with other organizations. Studies related to scale-up feasibility, systems integration, and subsystem design will also be involved. Performance criteria appropriate to the mission will be established for each system component, and develop-

ment programs focused to meet these criteria will be planned and implemented. These activities not only will involve major efforts at ORNL and in the Oak Ridge complex but also will include substantial subcontract or cooperative activities at other locations with complementary expertise.

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, power conditioning, and system reliability; and (3) for beam systems—ion-source design, fabrication and performance testing, and radio frequency (rf) quadrupole, linear accelerator, and beam-steering neutralization studies.

New funding is expected to be modest but adequate to start the program in FY 1985. In subsequent years, significant growth will be necessary to meet the mission schedules and objectives. Major activities both in-house and through subcontracting will be involved. Capital equipment will be required to support fuels and materials test facilities, thermal hydraulic and two-phase flow loops, and beam test facilities.

Protein Engineering and Bioprocess R&D

Methodology now exists to alter any amino acid residue of a protein by site-directed mutagenesis of its gene. ORNL plans to combine Laboratory expertise in protein biochemistry and molecular genetics to establish a new research initiative in protein engineering and

bioprocessing. This initiative will be linked to other important ORNL research activities, such as performing X-ray diffraction studies, determining detailed protein structure, developing position-sensitive detectors for recording diffraction patterns, sequencing and cloning genes, defining protein chemistry, and producing three-dimensional computer graphics. By using the sophisticated techniques of molecular biology, ORNL plans direct modification of genes to alter the structure of proteins in a predictable manner and thereby alter functional properties. Thus new gene products (proteins) would be built with desired properties—for example, enzymes that would be controlled in turnover number, thermostability, stability and/or activity in solvents other than water, substrate specificity, and pH optima. These modified proteins would be helpful in various bioprocess schemes.

While the techniques for enzyme engineering and recombinant deoxyribonucleic acid (DNA) have opened up new vistas for innovative biotechnology, most bioprocessing systems are still based on the technology of many years ago. ORNL will therefore also review the need for associated modern instrumentation that could be useful to bioprocess activities. The Laboratory goal will be to develop bioreactor concepts that are at least a factor of 10 more efficient than those used in current industrial practice. The final developments will include the use of multi-stage columnar systems that operate on a continuous basis and that use high concentrations of immobilized biocatalysts. These activities will supplement ongoing R&D activities associated with the ORNL Bioprocessing Research Facility user resource.

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