Oak Ridge National Labora

Celebrating 50th

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Institutional Plan
FY 1993–FY 1998

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ORNL/PPA-92/3

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Oak Ridge National Laboratory Institutional Plan FY 1993–FY 1998

Date Published—November 1992

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managed by
Martin Marietta Energy Systems, Inc.
for the
U.S. Department of Energy
under Contract DE-AC05-84OR21400

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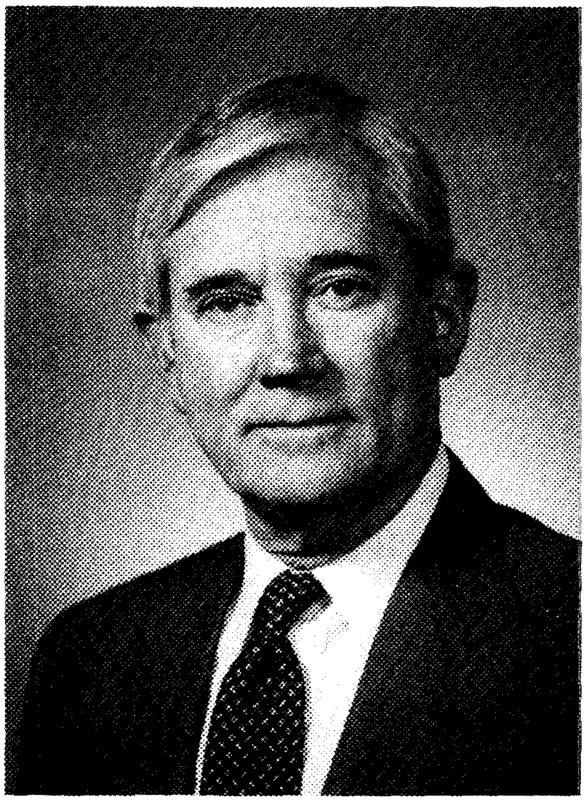
Fifty years ago this fall, Oak Ridge National Laboratory was established to serve a narrow, yet urgent national need: the separation of plutonium from irradiated uranium fuel. From this initial mandate—instrumental in ending World War II—the Laboratory has steadily broadened its scope to reflect the evolving scientific priorities of the nation and the world.



ORNL Director Alvin W. Trivelpiece

Today, ORNL activity can be grouped into five major categories: energy, environment, economic competitiveness, education, and the basic sciences. And while work is quite diverse, all of it fulfills ORNL's original mission of serving urgent national interests:

- balancing energy needs with environmental responsibility,
- deciphering the human genetic code to crack the mysteries of human development and disease,
- exploring solutions to our burgeoning waste problems, and
- engineering strong new materials for use by U.S. industry.

Over the past half-century, ORNL has made pioneering advances in each of these arenas. However, our ability to continue leading-edge research is determined largely by our freedom to build and maintain leading-edge facilities. Among our initiatives this year are two such facilities that will capitalize on expertise resident at the Laboratory and, in so doing, advance whole fields of science.

Advanced Neutron Source

The United States can take great pride in the invention of reactor-based neutron research. Pioneered at ORNL, neutron science led directly to the plastics revolution and to advancements in energy, medicine, agriculture, computing, and geology, among a host of other fields. Yet, despite its historic lead, the United States has fallen behind in this discipline so crucial to economic competitiveness.

Not only has the United States not built any new research reactors during the past 30 years, but existing facilities have deteriorated. As a result, there are huge areas of scientific inquiry the United States cannot explore. In the meantime, 10 large research reactors have been commissioned worldwide since 1980. Of these, one is in France, one is in Japan, and the other eight are in developing nations eager to reap the benefits of neutron science that the United States has demonstrated so convincingly.

The Advanced Neutron Source, proposed to be built at ORNL during this decade, embodies the United States' last, best hope for reasserting its leadership in this field. It would allow us to regain the advantage we lost to Western Europe a decade ago and would attract a new generation of researchers.

The centerpiece of the ANS will be the finest research reactor ever built, designed using every advance made since our last generation of research reactors was built. More than 1000 scientists and engineers per year are expected to use one of the more than 30 instruments the ANS will provide for experiments on materials and basic nuclear science.

The ANS is ORNL's top scientific priority, reflecting the importance the Department of Energy, the National Academy of Sciences, and others attach to the project as an essential element of our national research and development strategy.

Center for Biological Sciences

For more than four decades, ORNL has steadily expanded the frontiers of life science: first, by illuminating the biological effects of radiation; later, by pioneering methodologies for radiation and chemical risk assessment; more recently, by exploring the most basic life processes, including genetic replication and repair.

In the twenty-first century, we have the opportunity to unlock the detailed secrets of DNA and the human genome and, along with them, the causes and cures of many of humanity's gravest health problems: birth defects, developmental abnormalities, and many forms of cancer. Today's research tools are tomorrow's hope for better chemotherapies, high-yield biomass for food and energy, and new ways of diagnosing and treating genetic disorders.

The Center for Biological Sciences will bring together five key components, allowing new interactions and synergies: a transgenic mouse facility, a macromolecule mapping and engineering facility, a bioprocessing research facility, a mouse breeding center for human-disease models, and an expanded graduate school of biomedical sciences.

The talent and experience of ORNL's Biology Division represent one of the leading life sciences resources anywhere in the DOE complex, indeed, for some specialties, anywhere in the world. The many contributions these researchers have made to fundamental understandings of the most basic life processes have more than justified the investments made over the past four decades. However, to position ourselves to apply these resources to the challenges and opportunities of the next century, we must make an ongoing investment in them.

These kinds of investments—strategically targeted to capitalize on existing strength—represent this nation's only real hope for remaining a major force in the global marketplace of science and technology. As ORNL embarks on its second half-century, such federal commitment to our top-priority initiatives is essential if we are to continue serving the nation at a level commensurate with our ability and vision.

2 • Laboratory Missions

2 • Laboratory Missions

The Oak Ridge National Laboratory (ORNL), which is managed by Martin Marietta Energy Systems, Inc., (Energy Systems) for the U.S. Department of Energy (DOE), is one of the nation's premier research institutions. The primary mission of the Laboratory is to perform leading edge research and development (R&D) in support of the nonweapons roles of DOE. Especially important elements of ORNL's mission are to perform basic and applied research of importance to the nation, to provide the scientific and technical community with unique national user facilities, and to partner with universities and industry to improve the nation's competitiveness through technology development and transfer and through contributions to the national initiative to improve science and math education.

ORNL will accomplish the mission through its core competencies:

- energy production, conservation, and utilization technologies;
- materials sciences and engineering;
- physical, chemical, and engineering sciences;

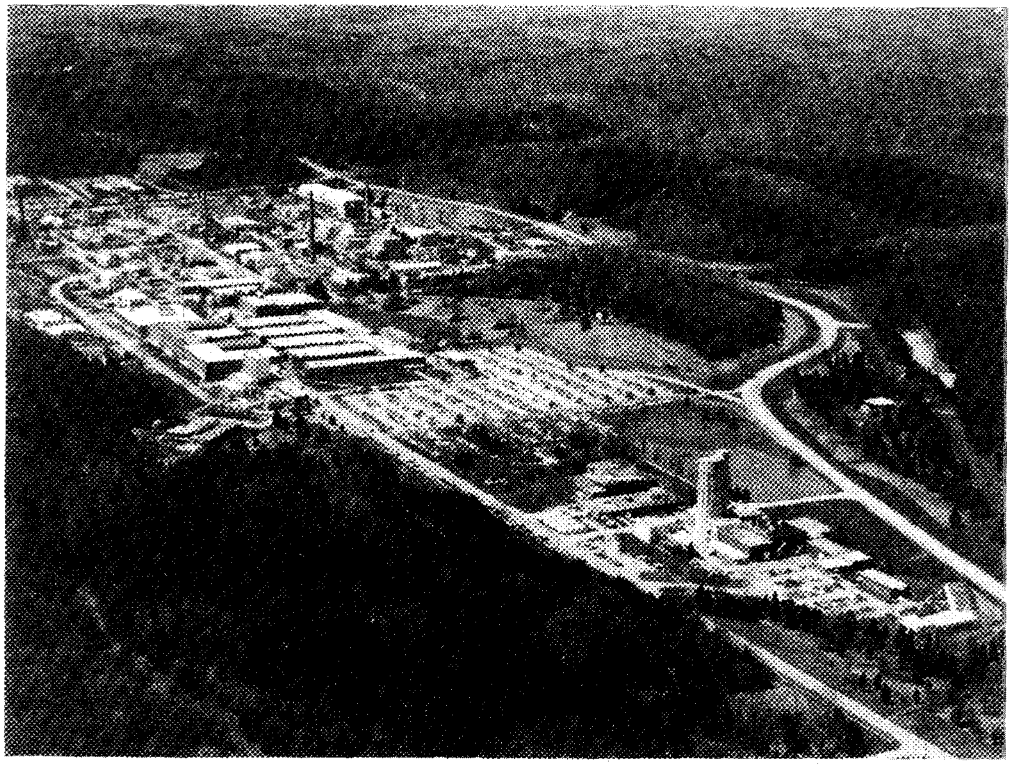


Figure 2.1
An aerial view of Oak Ridge National Laboratory

- biological and life sciences;
- environmental sciences and technologies;
- computational sciences; and
- manufacturing sciences and technologies.

The principal sponsor of ORNL's work is DOE, but, in a larger sense, the Laboratory serves many national—even international—customers. ORNL staff are involved in research on global environmental and energy problems, and in the development of technologies that will improve U.S. competitiveness in international markets. The Laboratory's more fundamental scientific research, much of which is done in collaboration with researchers from around the world, contributes to the storehouse of human knowledge; this work, therefore, has a very broad customer base. In the conception, construction, and operation of national research facilities, the Laboratory's customers are drawn from major segments of the scientific and technical community. Much of the applied research and technology development work at ORNL is expected to provide services for other government agencies and private companies.

Several factors combine to distinguish ORNL form other R&D institutions. The Laboratory melds a unique blend of excellent researchers with a large array of world-class facilities to conduct broad interdisciplinary research in areas of national importance. The ability to integrate basic research, applied research, technology development, information dissemination, and technology transfer is unsurpassed among research institutions. The style of teaming with industry and academia to bring a multidisciplinary approach to problem-solving provides exceptional value to ORNL's customers. Finally, the Laboratory's ability to conceive, construct, and manage large, complex projects provides DOE and the nation with a rare resource.

3 • Laboratory Strategic Plan

3 • Laboratory Strategic Plan

ORNL is one of the major multiprogram laboratories owned by DOE. These laboratories contain the largest collection of scientific talent and research facilities in the country, if not the world. This scientific power is essential to the United States in meeting the challenges we face in the next few years. These challenges fall into three categories—energy, environmental protection, and economic competitiveness. ORNL has strong capabilities and will continue to be a major contributor in all of these areas. The nature of these contributions over the next 15 years is the focus of the following strategic look to the future.

Situation Analysis

Over the next 15 years, energy will continue to grow in importance in the United States and worldwide. First, the world's largest reserves of oil lie in one of the world's most politically unstable regions; this situation is unlikely to change in the foreseeable future. Next, global energy production and consumption will continue to rise; this increase will, in the main, be driven by the developing countries. The impacts this will have on energy prices and the environment will focus attention on improved efficiency and on nonfossil energy supply and use technologies. The United States is faced with falling reserves of gas and oil, increased oil imports, and increasing concern about the environmental and health consequences of energy technologies. If our system is a rational one, these factors will add up to increased emphasis on energy R&D by DOE and its national laboratories. Because ORNL is one of DOE's largest energy research laboratories, we are in a good position to make major contributions to DOE's programs in energy R&D.

As the world population increases, and as this population becomes more affluent, the potential for global environmental change grows ever larger. At present, global warming and ozone layer depletion are the more visible environmental concerns, yet these are only examples of the broader environmental implications of a growing world economy. Global environmental issues will likely become even more important in the future. Unless we improve our knowledge base concerning global environmental processes, we will be ill-prepared to develop and to implement national and international policies to deal effectively with the environmental problems. Much more fundamental and applied research is required if we are to have the understanding needed for intelligent responses to environmental issues. DOE's laboratory system is an important key to gaining this knowledge. Because ORNL's environmental capabilities are among the nation's best, we are in a good position to make major contributions to humankind's understanding of the global environment.

A major revolution leading to fundamental advances in understanding the molecular basis of gene function is occurring in the biological sciences. ORNL's historic leadership in mammalian genetics, protein engineering, and molecular biology will continue with major contributions toward understanding the mammalian genome and the genetic basis of human disease. ORNL's research in protein engineering and structural biology will expand and will assume increasing national importance should DOE decide to proceed with the construction and operation of the Advanced Neutron Source (ANS); the neutron-scattering facilities at ANS will offer unmatched capabilities for probing complex biological structures that cannot be characterized by any other means.

The need to restore the United States' ability to compete in international markets is one of the most pressing problems facing this nation. It is not just a short-term issue. It is a structural problem with large scientific and technical components and with no quick fixes. Many things need to be done. We need to strengthen our educational system with special emphasis on scientific and technical education. We need to continue to replenish our reservoir of basic scientific knowledge. And we need to do a better job in helping American industry to translate the new knowledge into commercially useful products and processes. Secretary of Energy James D. Watkins has directed that the national laboratories take on the mission of helping the United States become more competitive through technology transfer and through contributions to scientific and technical education. In some ways this challenge is more difficult than the Manhattan Project, for which the national laboratories were founded nearly a half century ago. This challenge is difficult because it requires fundamental changes in the relationships of government, industries, and universities. In particular, the traditional sharp boundary between industry and government will need to be altered as it becomes evident that the nation must call upon all of its intellectual resources—universities, industries, and national laboratories—to work together toward a common goal.

Although R&D can address many of the important issues facing the nation, significant funding constraints will affect research. The federal deficit will continue to dampen new initiatives, and competition for research funds will increase. Because of cutbacks in defense spending, many of the defense R&D institutions will become stronger competitors for the civilian R&D dollar. DOE's environmental and waste problems will continue for a decade or more, and funding to address these issues will diminish resources available for R&D. The budget constraints will focus attention on the efficiency and effectiveness of DOE's laboratory system. Big science projects like the Superconducting Super Collider (SSC) and major user facilities like the ANS will come under increasing scrutiny. In attempts to cut spending, DOE may experience pressures to consolidate facilities. Any facility or program that consumes resources and does not produce significant scientific or technological advances will be at risk.

Vision and Strategic Objectives

The next two decades promise to be a most productive and exciting period in the history of the Laboratory. It will be a period of revolutionary changes in almost every area of science and technology in which ORNL is involved. It will also be a period of considerable challenge. Reflecting national needs, ORNL's directions will be dominated by three major themes—energy, environmental protection, and economic competitiveness.

Contributions to Competitiveness

Because of the competitiveness mission, collaborative research, centered on major user facilities, will become a very important component of the Laboratory's intellectual output. It is expected that the number of guest researchers will increase substantially over the next 10 years. Much of the increase in collaboration with outside researchers will be associated with the expansion of our existing user facilities and the addition of new facilities. Major new user facilities that we hope to put in operation over the next decade include the world's most powerful research reactor, the ANS; the Center for Biological Sciences (CBS); and the Materials Science and Engineering (MS&E) Complex. The ANS alone will accommodate 1000 users per year.

In addition to collaboration through user facilities, cooperative research and development agreements (CRADAs) created by the National Competitiveness Technology Transfer Act of 1989 (P.L. 101-189) provide industry with access to the varied R&D activities at DOE facilities. A CRADA allows ORNL to enter into cost-sharing arrangements with U.S. industry to improve our national competiveness. CRADAs provide an extremely efficient means of leveraging R&D funds.

To a growing extent, the exceptional scientific and technical developments coming from ORNL are being translated into new U.S. products, markets, and jobs. The catalyst for this evolution in the Laboratory's traditional role is an aggressive technology transfer program, one that recognizes the importance of face-to-face interaction between ORNL researchers and their industrial counterparts. This program began in 1985, and as of April 1992, the Laboratory had in place 63 licensing agreements with American industry. The cumulative product sales associated with these agreements are $40 million and are growing rapidly. ORNL has established itself as a leader in technology transfer, and we plan to continue that leadership in the future.

As another element of the competitiveness mission, the Laboratory will expand its already substantial educational programs. The present educational activities encompass over 40 programs involving precollege, undergraduate, graduate, and postgraduate students and faculty. The potential for our precollege program is particularly significant. If the United States is to regain its leadership in international commerce, we need to influence the nation's best and brightest young people to pursue scientific and technical careers. That is the aim of the Laboratory's Environmental and Physical Sciences Study Center, which attracted 20,000 precollege students and teachers last year. The center provides students with the opportunity for hands-on learning in the physical and life sciences.

Research and Development Programs

Energy Technologies

The future emphasis of energy R&D at ORNL will be on energy efficiency improvements (both supply and end-use technologies) and nonfossil energy supply technologies (including fission, fusion, and biomass energy). The Laboratory will continue to conduct a large and diverse R&D program in conservation and renewable energy. Conservation R&D emphasizes high-temperature materials for transportation and industry, technologies for increasing the efficiency and economical use of energy in buildings and industry, and strategies for improving the efficiency of electricity supply and use. To achieve maximum benefit for the program, conservation R&D activities are carried out in close collaboration with the private sector by means of subcontracting and CRADAs. Conservation work has resulted in 14 CRADAs thus far—50% of the total now being developed at ORNL.

Two major user centers are supported by the conservation work: the High Temperature Materials Laboratory (HTML) and the Roof Research Center. The objective at these centers is to develop and to test new materials and technologies that can reduce fuel use requirements across the economy.

Energy supply R&D will continue to emphasize renewable resources, nuclear fission, and nuclear fusion. Renewable energy R&D focuses on biomass and hydroelectric energy production. Under the Biomass Production Program at ORNL, techniques will be pursued to reduce the cost and to increase the productivity of woody and herbaceous biomass applicable to many regions of the country and in developing nations. Advanced technology for the conversion of biomass to fuels and chemicals will also be pursued. ORNL has a major role in DOE's Hydropower Program, which was reestablished in FY 1991. ORNL conducts R&D on environmental issues that limit hydroelectric development and provides data management and analysis support for hydropower resource assessment.

Nuclear R&D, including both fusion and fission, will continue at ORNL throughout the planning period. The energy released when light elements are "fused" offers humankind the potential for a limitless source of energy. ORNL plays an important role in the international quest to develop magnetic fusion as a practical energy source. The Laboratory's long-term strategy for fusion is to strive for scientific and engineering excellence in a broad program emphasizing technology and materials. In particular, work will continue on advances in steady-state confinement, plasma heating and fueling systems, first-wall and blanket materials, and applied plasma physics. In addition, the Oak Ridge Reservation is an excellent, nuclear-qualified site at which to build advanced fusion facilities.

ORNL plans to continue a contributing role in development of technology for advanced fission reactor concepts and space reactor applications. DOE's current program includes two advanced commercial reactor concepts: the modular high-temperature gas-cooled reactor (MHTGR) and the liquid-metal reactor (LMR).

A continuing initiative is ORNL's collaboration with the Massachusetts Institute of Technology to further develop a concept first proposed for the high-temperature gas-cooled reactor (HTGR) in the 1970s. By eliminating the steam generator and using the hot helium gas that exits the core of the MHTGR to drive a gas turbine, a considerable gain in efficiency can be achieved. The "direct cycle" (DC) MHTGR can have efficiency in the 50% range, compared with 37% for the SC and 33% for water-cooled reactors operating on the SC. The MHTGR-DC is just one of several advanced applications for gas-cooled reactors now being considered at ORNL.

Waste Management and Environmental Restoration Technologies

The Laboratory is aggressively pursuing R&D in environmental restoration and waste management. The emphasis is on developing, demonstrating, and testing technologies that address environmental restoration and waste management problems throughout Energy Systems. Energy Systems' concerns are so diverse that issues facing them invariably apply to other sites within the DOE complex. To that end, staff members work closely with Energy Systems' Environmental Restoration and Central Waste Management divisions to propose solutions to problems that they have identified. The goal is to solve problems rapidly in the most cost-effective manner possible without undue risk to human health or to the environment.

Physical Sciences

The Laboratory will maintain vital programs in both the physical and life sciences. The science programs serve two important purposes: they add to the storehouse of fundamental knowledge, and they create a strong scientific base in support of the Laboratory's technology programs. Areas of research in the physical sciences will include materials; computations; robotics and intelligent systems; chemistry and chemical engineering; and atomic, nuclear, and high-energy physics.

The goal of the ORNL materials program is to continue as a world leader in high-temperature materials development and solid state physics, including surface research, preparation of new materials, advanced materials processing, and neutron scattering. The materials programs are coordinated among the participating divisions to cover a multidisciplinary agenda from basic research through development and applications to technology transfer. The materials systems studied include metals and intermetallic alloys, ceramics, superconductors, composites, polymers, and semiconductors. The materials programs are responding to the National Advanced Materials and Processing Initiative to focus new and continuing research efforts on this important program. Planning is also under way for the upcoming initiative on advanced manufacturing, which will also crosscut the physical sciences divisions. In addition, the materials programs strive continually to develop new and more accurate characterization and analysis facilities and to make these available to outside researchers from industry and universities.

Neutron scattering, materials irradiation and testing, nuclear physics, specialty isotope production for research medical and military applications, and structural biology research continue at the High Flux Isotope Reactor (HFIR). Neutron-scattering research will continue to increase in importance as more disciplines utilize this unique characterization capability, as industrial use increases, and as the international cooperation aiming at the

ANS increases. Future advances in neutron-scattering research depend heavily on the ANS Project.

An area of increasing emphasis will be in computational science: developing and utilizing state-of-the-art parallel computers. A new Center for Computational Science (CCS) has been established to support existing computational efforts, and the use of parallel computing will be broadened to support all the physical and life sciences. In robotics and intelligent systems, research topics will include teleoperations and autonomous systems; human-machine symbiosis is the ultimate goal.

Chemistry and chemical-engineering research will emphasize high-temperature aqueous and geochemistry, materials chemistry, actinide science, separation science and technology, fossil resource science, photochemistry and biophotochemistry catalysis, and biochemical-engineering research for recycling and treating waste. In analytical chemistry, new and more accurate analytical techniques will be developed to meet the research needs of ORNL, as well as new standards in analysis for ES&H needs. Mass spectrometry, new ion source and sampling techniques, and increasing use of lasers will continue.

In physics the addition of new research capabilities to the Holifield Heavy Ion Research Facility (HHIRF) will keep ORNL a world center for nuclear structure research—at least through the end of the century. This will include the development of a capability for exotic radioactive ion beams, completion of the recoil mass spectrometer, and continued ion-source and acceleration improvements.

Environmental, Life, and Social Sciences

Biological, environmental, and health sciences will continue to prosper as essential elements of the Laboratory's research programs. The proposed Environmental, Life, and Social Sciences (ELSS) Complex will provide new, high-technology research facilities for a number of disciplines. In biology the plan is to build on the core areas of mammalian genetics, molecular biology, and protein engineering. In addition, it is planned to expand multidisciplinary research in structural biology and genome mapping.

The proposed new biology facilities will provide modern, cost-effective space to maximize ORNL's competitiveness in biological research. Enhanced efficiency and diminished security restrictions will facilitate interactions with the external community and will be compatible with establishing user facilities for specialized techniques such as neutron scattering and insertional mutagenesis.

Health and safety research will continue its focus on the measurement and assessment of human health impacts of radiological and chemical substances. Emphasis will be on developing further the recently formed Center for Risk Management, improving the understanding of pollutant interactions at the atomic and molecular levels, enhancing studies of the liquid state of matter, developing imaging methodologies for a broad range of biological samples, developing hybrid instruments for chemical mapping, and developing advanced photonics for environmental and biomedical applications. Progress will continue in the development of radiopharmaceutical products for routine clinical applications, advanced information management techniques, and state-of-the-art site characterization methods and instrumentation. Important goals are to continue to maintain world leadership in radiation dosimetry and to establish centers of excellence in health risk analysis and health physics instrumentation.

In the environmental sciences the broad goal is to retain the Laboratory's status as one of the world's premier ecological-environmental research centers. The environmental sciences program will cover both energy-related environmental issues and global science. An important objective is to understand from these studies the interactions of physical and chemical agents with living organisms, including the ultimate consequences on the environment. Global environmental studies will be directed toward gaining the fundamental understandings needed to deal intelligently with the major global-change issues, including global warming. One of the goals is to provide practical input to decision makers for making technology and policy decisions.

Efforts will continue in the analysis and assessment of energy and environmental issues [energy and resource analysis, National Environmental Policy Act (NEPA) program management, research on waste management and emergency preparedness, and energy analysis of developing countries]; and in conducting work on military and civilian transportation systems.

Applied social science research includes work on the economics and social acceptance of energy technologies. The latter involves such issues as risk perception, conditions for public trust, and the evaluation of factors external to the market. Social scientists are also engaged in evaluating the effectiveness of government and utility programs to encourage the efficient use of energy and to understand better the variables important in the adoption of new technologies. A particularly important aspect, which is also a programmatic initiative, is the transfer of technology to developing and Eastern European nations.

Work for Others

The Laboratory will continue to provide vital R&D support to the Nuclear Regulatory Commission (NRC) as well as to other federal and nonfederal agencies. Over the past two decades our Work for Others (WFO) Program has grown to become a critical component of our overall R&D activities—providing an important outlet for our staff to explore issues and problems that complement our DOE mission. Much of the past research has involved support to various DOD agencies, the U.S. Department of Health and Human Services and the National Science Foundation, but in recent years a shift has begun to such agencies as NASA, the U.S. Environmental Protection Agency (EPA), and the U.S. Department of Transportation (DOT). Private organizations such as the Electric Power Research Institute also fund significant efforts at ORNL.

Strategic Issues

Progress in the thematic areas of energy, environmental protection, and economic competitiveness will require the Laboratory's and DOE's managements to concentrate on four issues. First, the infrastructure of the Laboratory must be rebuilt. At the same time, ORNL needs to be able to manage its available resources to achieve excellence in operations relative to environmental, safety, and health (ES&H) protection while maintaining a suitable environment for performance of world-class R&D. Additionally, we must continue to expand our interactions and collaborations with outside organizations, especially universities and American industries. Finally, and most important, we must enhance our ability for attracting, developing, and retaining quality staff.

Rebuilding and expanding the infrastructure of ORNL requires management attention to decommissioning several "legacy" facilities, upgrading most existing facilities to meet current safety and environmental standards, replacing some existing buildings, and acquiring new research facilities to serve as national user facilities. The most important of these new user facilities is the ANS; the Materials Science and Engineering and the Environmental, Life, and Social Sciences complexes are also high-priority facility needs.

Although the Laboratory has made significant progress in meeting ES&H needs and requirements, much remains to be done. The challenge is complex, especially given the age of our facilities, increasingly rigorous DOE and other agency regulations, and limited financial resources. To address the most critical ES&H needs first within available resources, ORNL and DOE must continue to work together to establish priorities. And all this must be accomplished without jeopardizing the Laboratory's current and future R&D viability.

Continued expansion of the Laboratory's interactions and collaborations with outside organizations will require considerable effort to make ORNL more "user friendly." Both the DOE and ORNL managements will need to pay more attention to simplifying general access and user agreements, streamlining approvals for foreign nationals, and providing services for guest researchers.

Johnston and Packer, as well as authors of other demographic studies, predict a future shortage of the kinds of people the Laboratory needs.[1] This means that management will need to pay much closer attention to remaining competitive in hiring, developing, and retaining a highly competent staff. Attention must, of course, be paid to being competitive in salaries, but benefit packages and opportunities for career development will be even more important. Special attention will need to be paid to the needs of working mothers, single parents, and employees with diverse cultural backgrounds.

Strategies

ORNL's newly established R&D Strategic Planning Committee is currently working toward developing a new strategic plan for the Laboratory. A situation analysis of the Laboratory's strengths, weaknesses, opportunities, and threats has been completed. The committee has defined specific goals and performance measures for determining goal achievement; it will define strategies also for achieving each of these goals. In addition, it will produce an action plan to ensure measurable progress toward achieving each specific goal.

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[1]William B. Johnston and Arnold E. Packer, *Workforce 2000: Work and Workers for the 21st Century*, Hudson Institute, Indianapolis, June 1987.

4 Summary of Major Initiatives

4 • Summary of Major Initiatives

ORNL's newly established Research and Development Strategic Planning Committee has chosen the major Laboratory-wide initiatives presented in this section. Other programmatic initiatives are listed at the end of this section and described in Sect. 5, "Scientific and Technical Programs," under the program from which funds are being sought.

These initiatives are provided for consideration by DOE. Inclusion in this plan does not imply DOE approval of, or intent to implement, an initiative. Resource projections (Sect. 10) do not contain funding for any of the new initiatives.

Advanced Neutron Source

The ANS Project will provide an intense, steady-state neutron source to support research programs that broaden the body of knowledge on which today's applied technologies rest and will allow research on new technologies that will be important in the coming decades (Fig. 4.1).

A portion of the mission needs of the ANS is currently provided by the HFIR and the High Flux Beam Reactor; however, these existing facilities are more than 25 years old,

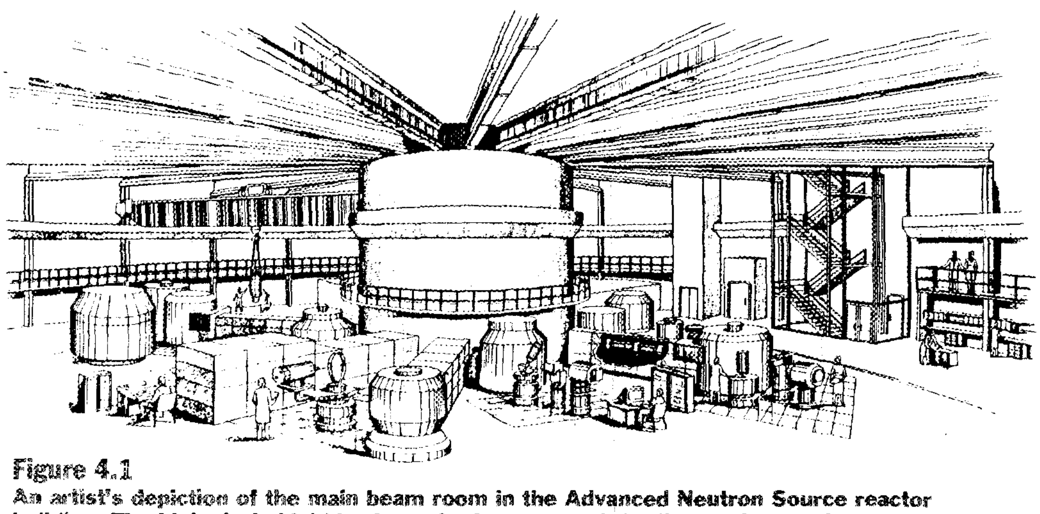

Figure 4.1
An artist's depiction of the main beam room in the Advanced Neutron Source reactor building. The biological shield is shown in the center of the figure. Beam tubes transport neutrons to instruments arranged radially in all directions from the reactor. A typical instrument consists of beam collimation and filtering systems, a sample chamber, and some type of analyzer and detector system that measures neutrons scattered off the sample over a range of angles.

and they cannot be modified to meet future neutron research needs effectively. The ANS will be able to replace both of these facilities and will greatly enhance the research capabilities in neutron scattering for condensed matter physics, materials science, chemistry, and biology. In addition, the ANS will maintain or improve capabilities for special isotopes production (such as californium), materials irradiation studies, neutron activation analysis, and nuclear physics.

Specific technical objectives for the ANS are established with the help of the National Steering Committee for an Advanced Neutron Source, which comprises more than 30 representatives from DOE laboratories, the National Institute for Standards and Technology (NIST), universities, and industries. The steering committee provides a forum for the various user communities to identify anticipated needs and to weigh the trade-offs associated with conflicting requirements between the different technology groups.

To achieve the project's performance criteria, a small, high-specific-power reactor design (cooled, reflected, and moderated by heavy water) has been devised. As with DOE's Advanced Power Reactor Program, maximum use has been made of passive safety features. Other safety-related design features include two independent, diverse, and redundant shutdown systems. In addition, the reactor is placed in a large, double-walled containment dome.

Corrosion of aluminum alloy fuel cladding may pose temperature and structural problems associated with the formation of an oxide layer during the lifetime of the core. Earlier research, mostly in support of the HFIR and the Advanced Test Reactor designs, indicated that under extreme heat-transfer conditions the exposure of aluminum and many aluminum alloys to water leads to the growth of an adherent oxidation product of significant thickness. At the anticipated high-heat flux levels for the ANS core (of the order 6 to 11 MW/m2), interspersing an oxide film of low thermal conductivity between the fuel plates and the cooling water may in certain instances lead to plate overheating. To ensure that both the fuel and cladding integrity are maintained under unique conditions imposed in the ANS fuel plates, an experimental facility was constructed to allow detailed study of this type of corrosion behavior for a wide range of thermal-hydraulic conditions.

The Corrosion Test Loop Facility has been in virtually continuous operation since its installation in January 1988. Briefly, the test apparatus is based on a forced-flow water loop fabricated entirely of type 304L stainless steel components, operating at pressures up to 7 MPa. The loop is completed by a specimen of the sample aluminum alloy in the form of a tube enclosing a rectangular flow channel that has the same narrow dimension (1.27 mm) as the gap between ANS fuel plates. The overall channel dimensions allow tests up to coolant velocities of 30 m/s at the maximum flow rate (2 L/s). The specimen is welded to large electrodes, installed into the main section of the loop, and surrounded by electrical and thermal insulation and pressure backing. The heat flux (up to 20 MW/m^2) is produced by Joule heating of the specimen using a 30-kA dc power supply; downstream of the specimen, the heat is removed by a water-cooled heat exchanger. A low-pressure bypass (cleanup) line is used in the same way as in a typical reactor to permit instrumentation and to provide water chemistry control within the loop, principally by deionization followed by pH control using nitric acid addition.

In addition, a thermal-hydraulic test loop has been constructed and is in operation to verify the correlations used to determine critical heat flux, flow stability, and other parameters determining the safety margins. This is necessary because there are few existing experimental data under the high heat flux and coolant velocity expected in the ANS reactor core.

The ANS conceptual design has been completed, with issuance of the conceptual design report in June 1992. A reference design for the primary and secondary cooling systems, conceptual designs for the layout of the experimental and operational equipment and space requirements, and for the detritiation/heavy water upgrade plant were defined and documented in that report. The project schedule indicates that reactor startup would occur in FY 2002, which approximately coincides with the estimated end-of-useful-life for the existing reactors. Budget projections for the planning period are given in Table 4.1.

Table 4.1
Budget projections for the planning period by fiscal year for the Advanced Neutron Source
($ in millions—BA)[a]

	1993	1994	1995	1996	1997	1998
Operating expense	21.0	14.1	23.9	31.6	42.3	66.2
Capital equipment	1.0	2.2	3.9	2.2	2.3	0.8
Design-only line item		43.2	56.4			
Construction line item			32.2	168.5	359.5	600.2
Total	**22.0**[b]	**59.5**	**116.4**	**202.3**	**404.1**	**667.2**

[a]Actual dollars.
[b]President's Budget.

The ANS has been supported through the DOE Office of Basic Energy Sciences (DOE-BES) and is managed by the DOE Office of Nuclear Energy (DOE-NE).

Design and construction of a reactor that will meet all of the performance criteria are considered feasible. The need for early documentation of safety analyses and for preparation of the EIS prior to a commitment of detailed design prompts a phased approach to the project, structured as a Title I design-only phase (FY 1994–1995), followed by a design completion and construction phase (FY 1995–2002). This provides an FY 2002 goal for reactor startup, with design proceeding at a controlled pace to allow for resolution of the remaining uncertainties. The approach also reduces the risk of future schedule delays and cost growth by providing a firm design basis before construction funds are committed.

Environmental, Life, and Social Sciences Complex

The development of the ORNL ELSS Complex has been a vision of the Laboratory for many years. The expansion of the West End Development Area of ORNL is of extreme importance to accommodate the growing programs within the environmental, life, and social sciences and will also support DOE's increasing emphasis on ES&H activities. The ELSS Complex will provide new high-tech laboratories for expanding R&D needs of the Biology, Health and Safety Research, Environmental Sciences, and Energy divisions and will offer modern facilities in place of old buildings that are often crowded, inefficient, and in need of repair. New facilities will consist of three proposed line items (CBS, the Earth Systems Facility, and the Biological Imaging and Advanced Photonics Laboratory) as well as a number of general plant project (GPP) upgrades.

These will all be located in the vicinity of existing structures in the Environmental Sciences Division (ESD) (Fig. 4.2), which will enhance collaborative interactions within the directorate. Programmatic emphases in the directorate will be on structural biology, protein engineering, biotechnology, the human genome, global environmental studies, risk management, environmental restoration, social sciences, energy technologies for developing countries, the energy and environmental aspects of transportation systems, and energy efficiency. Table 4.2 provides budget projections for the ELSS Complex. Funding will be obtained from a variety of sources, including the Office of Energy Research.

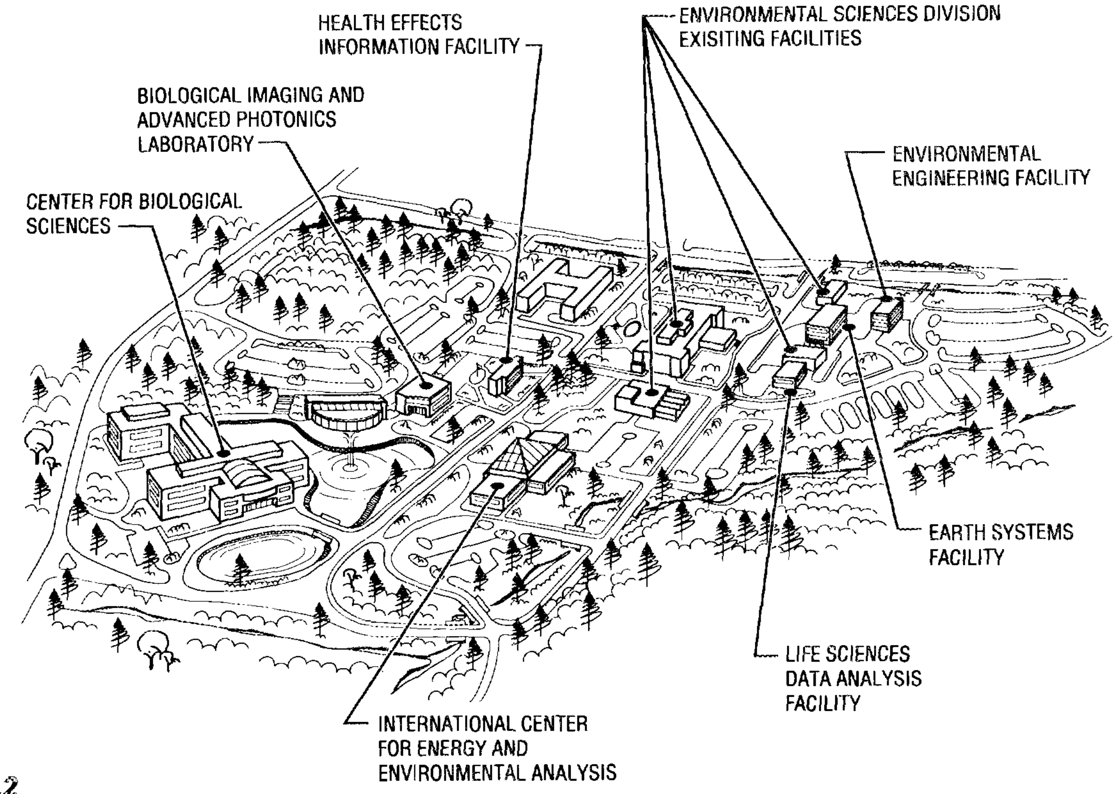

Figure 4.2 Conceptual plan for the ORNL Environmental, Life, and Social Sciences Complex (West End Development Area)

Center for Biological Sciences

The purpose of the CBS is to provide a facility that will promote and enhance the future research goals of the ORNL Biology Division and the University of Tennessee (UT) Biomedical Sciences Graduate School. These goals include protein engineering, structural biology, genome research, and chemical and radiation mutagenesis and carcinogenesis. The present Biology Division facilities at the Y-12 Plant are nearly 50 years old and are obsolete. Because of their condition, they are impediments to both ongoing and proposed research. Studies have shown that the costs of retrofitting current buildings to meet present needs would equal if not exceed the cost of a new building; preliminary estimates are that the operating cost savings resulting from moving out of the present facilities would be significant. Security at the Y-12 site is also an impediment to scientific collaboration with outside scientists, especially those from "sensitive" countries. The 8-mile separation of current Biology Division facilities from the X-10 site constrains collaborative efforts on key initiatives such as biotechnology (interaction with the existing ORNL Bioprocessing Research Facility) and structural biology (interaction with the proposed ANS discussed in the previous section). The proposed CBS will correct these deficiencies and will strengthen ORNL's contributions to these and other initiatives.

The CBS will be a two-story structure, as shown in the conceptual drawing given in Fig. 4.3, and will be of steel frame and masonry construction. It will be designed with a central core that houses division-wide research support and administrative functions and three interconnecting wings that house the division's laboratory and animal facilities. The building will be zoned by functions with proximity of various functions arranged to provide high-efficiency operations. Examples of the functions are (1) animal facilities for housing and caring for a diversity of mouse genetic strains, including animal rooms, cage and bottle-washing stations, and feed and bedding storage; (2) biochemical research space for

Table 4.2

Budget projections[a] by fiscal year for the Environmental, Life, and Social Sciences Complex development

($ in millions—BA)

	1993	1994	1995	1996	1997	1998
Program KP						
Center for Biological Sciences[b]	0.2/0	0/16	0/41	0/39.5		
Biological Imaging and Advanced Photonics Laboratory				0/1.5	0/6.5	
Earth Systems Facility	0.3/0	0.3/0	0.4/0	1.5/2	0/10	0/7
Program EW/AT (General Plant Projects)[c]						
Environmental Biotechnology Laboratory Expansion			0/1.1			
West roads and parking improvements		0/1.1				
Environmental Engineering Facility	0/1.1					
Other Construction						
International Center for Energy and Environmental Analysis[d]	0/0.78	0/1.02	0/0.72	0/0.72	0/0.48	
Steam system upgrade, West End[e]	0/5.0	0/2.9				

[a]Operating expense/capital equipment.

[b]The budget projection for the Center for Biological Sciences reflects the current budget submission, which assumes construction starts in FY 1994.

[c]Not listed are the Life Sciences Data Analysis Facility, which was approved in FY 1990, and the Health Effects Information Facility, which was approved in FY 1992. Each of these has a cost of $1.1 million.

[d]This facility is proposed as an expense-funded, leased modular building.

[e]Program KG, capital costs only.

conducting mammalian genetics, cancer biology, molecular genetics, structural biology, and protein engineering research including labs, equipment space, and office space for scientists, technicians, guests, and students; (3) UT Biomedical Sciences Graduate School; and (4) administrative operations such as library, computer center, editorial offices, and division administration. The facility's size is estimated to be about 250,000 ft^2.

A wide diversity of special facilities required by the ORNL Biology Division will be integrated in the facility in an efficient and a cost-effective manner. Examples of these facilities include areas suitable for gamma and X-ray irradiation, barrier areas for working with specific pathogen-free animals or hazardous materials, darkrooms, electron microscopy facilities, environmentally controlled rooms, tissue culture areas, and glassware kitchens.

In addition to the efficient arrangement of space, the facility's mechanical systems will be designed and installed to provide efficient use of energy while providing an adequate environment for animals, research, and personnel. Suitable space will be provided for telecommunications equipment within the building. Distribution networks for both standard voice and data communications will be provided. Site preparation will consist of clearing, grading, and excavating for new structures; extension of access roads to the site and installation of parking space; and landscaping, seeding, and site restoration. Outside

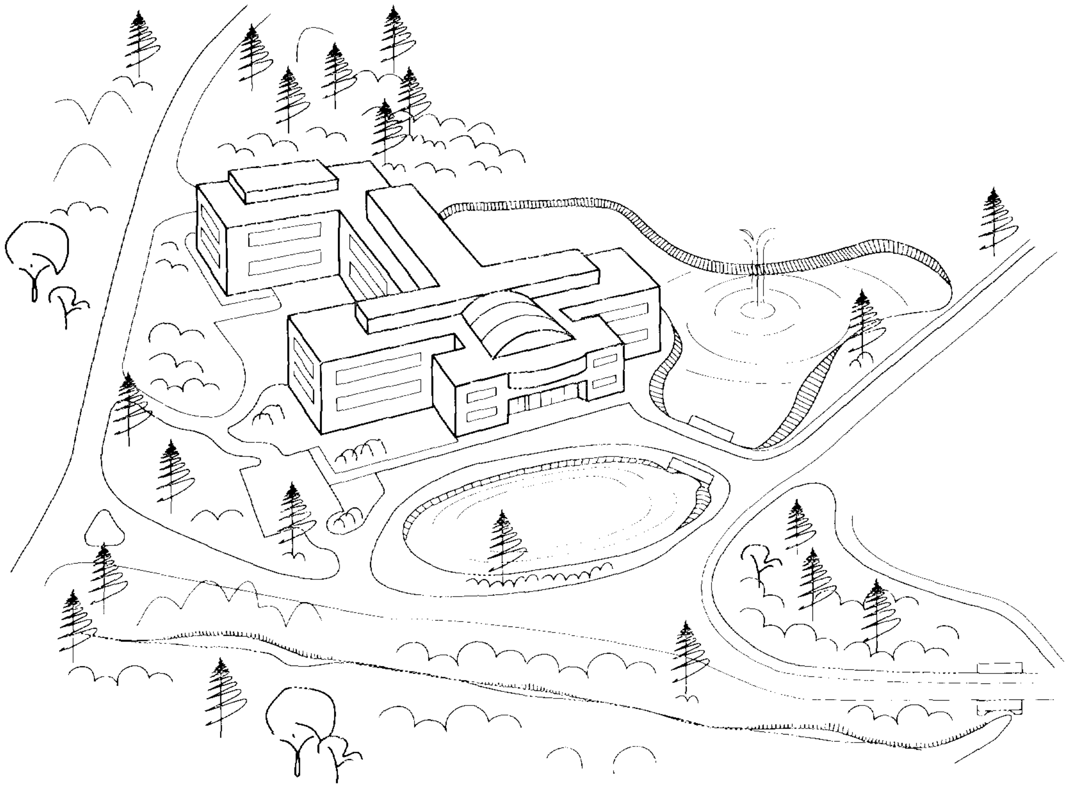

Figure 4.3 The ORNL Center for Biological Sciences

utilities will consist of extending the required utilities from the closest adequately sized location to the building. Examples of these are steam, sanitary sewers, potable and fire-protection water, and electricity.

Funding for FY 1994 for the construction of the CBS in the ELSS Complex is being pursued through the Office of Energy Research [Office of Health and Environmental Research (OHER)]. The total estimated cost of the facility is $96.5 million. The total project cost is about $97.5 million. A revised project data sheet (1B7 Form) was submitted to the Office of Energy Research in May 1992. A field-work proposal (FWP) has been submitted to OHER for FY 1992 and FY 1993 operating funds to prepare preliminary project documentation for identifying the CBS as a major construction line item and to generate the necessary supporting data. The review for the CBS validation was held in Oak Ridge in May 1992. FY 1992 funds were received for pre-Title I activities and other planning tasks for the CBS.

Earth Systems Facility

The purpose of the Earth Systems Facility is to support major OHER/ESD initiatives in Global Change, Subsurface Science and Ecological Research. These initiatives incorporate a diversity of specific projects, including Atmospheric Radiation Measurement (ARM), the Carbon Dioxide Information Analysis Center (CDIAC), Carbon Cycle Modeling, Colloid Transport, Environmental Biotechnology, Spatial Heterogeneity, the Walker Branch Watershed, Theoretical Ecology, and the National Environmental Research Park. Multidisciplinary approaches involving bioigeochemical cycling, model development and evaluation, hydrology, climatology, geographic information systems and mapping, and data management draw upon field-oriented, laboratory, computational, and theoretical staff. This facility will be dedicated to better integration of empirical research, modeling, and data systems activities; better integration is an essential step for the success of these new initiatives.

There are two principal needs for this facility. The first is a need for a facility that can accommodate the unique physical requirements of computing research. The structure of existing facilities does not enable the necessary networking capabilities for successful modeling and data management integration activities. In addition, laboratories designed for computing research are lacking, and power supplies are inadequate for computing tasks. The second need is of integrated measurement, modeling, and theoretical research. The groups supporting the Global Change, Subsurface Science, and Ecological Research initiatives of OHER/ESD are currently dispersed in six buildings. It is essential that modelers, researchers conducting experiments and making field measurements, and data systems staff have space for laboratories, offices, and computational facilities in reasonable physical proximity. Adequate, nearby work space will facilitate the iterative process of models leading to measurements and to improvement of the data bases to address the complex issues embedded in the OHER/ESD major initiatives at ORNL. Consolidation of ORNL staff in this new facility will enhance communication, stimulate new ideas, and improve research efficiency.

Biological Imaging and Advanced Photonics Laboratory

The purpose of the Biological Imaging and Advanced Photonics Laboratory is to serve as a focal point for integrating diverse activities in biological imaging and advanced photonics, as associated with the programmatic initiatives on advanced environmental photonics and the Biological Imaging and Analysis Center (see Sect. 5). It would also support the Biological and Environmental Research Program initiative of the ORNL Genome Program. In photonics, breakthroughs in areas such as advanced laser and fiber-optic spectroscopy are increasingly critical for applications in characterizing and monitoring during energy production, in defense operations, and in DOE's accelerated programs for environmental restoration and waste management and biological research. Biological imaging is tied to the use of electron scanning tunneling microscopes (STMs), atomic force microscopes (AFMs), and photon scanning tunneling microscopes (PSTMs) for providing images of biological samples. Future research will include development of methodologies for a broad range of biological samples, development of hybrid instruments for chemical mapping, and the use of combined infrared and optical spectroscopy for chemical mapping of biological samples using the PSTM. Collocating the scientific staff and research equipment for these two initiatives will lead to synergisms in the areas of photonics and biological imaging. The facilities will consist of laboratories and offices with a total floor space of about 12,000 ft^2 and a total cost of about $7 million. Programmatic funding is being pursued from a variety of sources, including OHER.

General Plant Projects

The GPP will consist of the Life Sciences Data Analysis Facility, the Health Effects Information Facility, and the Environmental Engineering Facility. Expansion of existing space in ORNL's Environmental Sciences Division is being considered to augment ORNL's resources for biotechnology research. Each facility is estimated to cost $1.1 million.

In general, the facilities will consist of office space, computer laboratories, computer rooms, and conference rooms. A multitude of programs and funding sources would be served by these facilities, and they are not tied to specific initiatives described elsewhere in this Institutional Plan.

Other

The International Center for Energy and Environmental Analysis will house Energy Division staff who work on social science issues, the energy and environmental aspects of transportation systems, energy efficiency, and EISs. Work done in this facility will support the Laboratory-wide transportation initiative, the ORNL Global Environmental Studies Program, the Center for Risk Management, and the Conservation and Renewables Program initiative of Energy Technologies for Developing Nations. Staff who would occupy this facility are currently spread out among a number of buildings at ORNL, and consolidation of the staff into this new facility would promote collaboration in the above areas. The facility is proposed as an expense-funded, leased modular building, with a total floor space of about 35,000 ft^2. It would include office space, rooms for minicomputers, and meeting space.

Supplementing the above facilities will be a lodge and conference center and other ancillary support structures that will enhance collaboration with the scientific community outside of ORNL and will help promote interactions with universities, industry, and other laboratories in areas related to environmental, life, and social sciences.

Materials Science and Engineering Complex

The ORNL MS&E Complex will consolidate a number of existing ORNL programs and incorporate new buildings and facilities to enhance collaborative interactions in MS&E. The complex will be constructed in the late 1990s in the undeveloped foothills area to the east of the present X-10 site (Fig. 4.4). The MS&E Complex will include a new Solid State Research and Processing Science Center, a Center for Advanced Microstructural Analysis (CAMA), a Center for Study of Advanced Materials (CSAM), a Composite Materials Laboratory, and an Office of Guest and User Interactions (OGUI). The plan of the complex addresses identified national, regional, and local needs for materials R&D, and it will support ORNL's rapidly expanding user programs and technology transfer activities. The CSAM is an initiative of the university community of the Southeast led by the Southeastern Universities Research Association (SURA). This center will encourage joint materials research activities with ORNL by establishing a university/industry presence at the MS&E Complex.

The MS&E Complex also meets a critical need to alleviate the severe crowding in materials facilities at ORNL. The need to replace substandard Solid State Division laboratories has been recognized for decades, and during this time their condition has considerably worsened. The Solid State Research and Processing Science Center will satisfy the need for modern solid-state laboratories at substantially lower cost than refurbishing existing structures to meet present ES&H and Occupational Safety and Health Administration (OSHA) standards. The CAMA is a response to the need for buildings capable of housing the next generation of instrumentation with vibration-sensitive electron optics. A new building will house such instrumentation and also bring together under one roof a full range of modern microanalytical instrumentation. The added space will alleviate severely overcrowded conditions in the Metals and Ceramics Division.

A recent study by the National Research Council demonstrates that materials science and engineering is one of the most rapidly developing areas of science—one that is vital to the future competitiveness of the United States in the international marketplace.[1] During the past decade it has become increasingly clear that the need exists for both cutting-edge research and close cooperation among universities, industries, and national laboratories that can carry ideas rapidly from inception to the marketplace. As a follow-on to the National Research Council MS&E study, the Office of Science and Technology Policy

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[1]National Research Council, *Materials Science and Engineering for the 1990s: Maintaining Competitiveness in the Age of Materials*, National Academy Press, Washington, D.C., 1989.

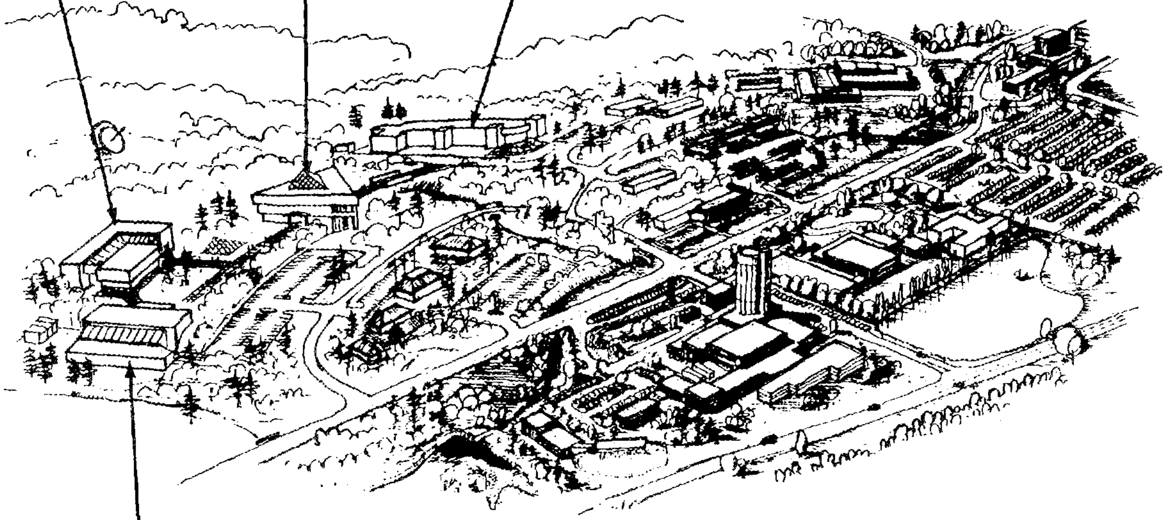


Figure 4.4 Proposed Materials Science and Engineering Complex to be constructed east of the current X-10 site

has drafted a national plan for MS&E to coordinate this area to meet the nation's future needs. This plan has formed the basis for a presidential initiative that has resulted in a substantial increase in materials R&D funding beginning in FY 1993. ORNL will structure the MS&E Complex to coordinate with this plan. An R&D center is envisioned that makes the ORNL materials facilities as well as those of the universities and industries in the region available for joint cooperative projects.

Materials R&D is the cornerstone of high technology, and ORNL has one of the strongest materials programs among the DOE national laboratories. Indeed, the ORNL programs in high-temperature metals and alloys, ceramics, composites, and superconductors are unparalleled successes. ORNL has established programs in synthesis and processing science that span a wide range of materials systems. ORNL is also a leader in user programs and technology transfer through CRADAs and licensing. These activities have grown rapidly and will increase even faster because of recent congressional legislation removing barriers to technology transfer.

The MS&E Complex is a recognition of the dual need to perform and to exploit materials R&D in the changing conditions of the 1990s. The MS&E Complex will provide ORNL with a much-needed replacement and expansion of its materials R&D facilities as well as a cooperative environment that will enhance R&D effectiveness and promote technology transfer. Marketplace success requires the active participation of U.S. industry. Industry must guide and participate in the R&D and manufacturing science activities. The nation's competitiveness can be enhanced by taking advantage of the technology transfer opportunities emanating from universities and national laboratories. Industry can make use of our wide-ranging multidisciplinary skills: our fabrication, characterization, and test capability; our independent, objective outlook; and our ability to work with and protect proprietary information.

Universities and colleges in the southeastern part of the United States have numerous innovative materials R&D programs that collectively span a broad range of disciplines from materials chemistry to materials physics to materials engineering and testing. During the last few years SURA and the Oak Ridge Associated Universities (ORAU) have explored ways to simplify and to encourage joint materials research activities with ORNL. This approach not only benefits large, well-established programs but also enhances individual small programs at the universities through synergistic interactions. A close working relationship between The University of Tennessee, Knoxville, (UTK) and ORNL is already well established. Faculty and graduate students from UTK participate in collaborative research with the staff at ORNL, and the staff at ORNL serve as adjunct professors and thesis advisors at UTK.

Center for Study of Advanced Materials

As the result of a regional materials science workshop sponsored by SURA and other organizational meetings between SURA and ORAU, the establishment of a campus-like presence at ORNL in the form of a CSAM for materials science and engineering has been proposed to increase the materials impact of the member universities (Fig. 4.5). The goals of the CSAM would be to develop broadly based scientific initiatives in materials science and

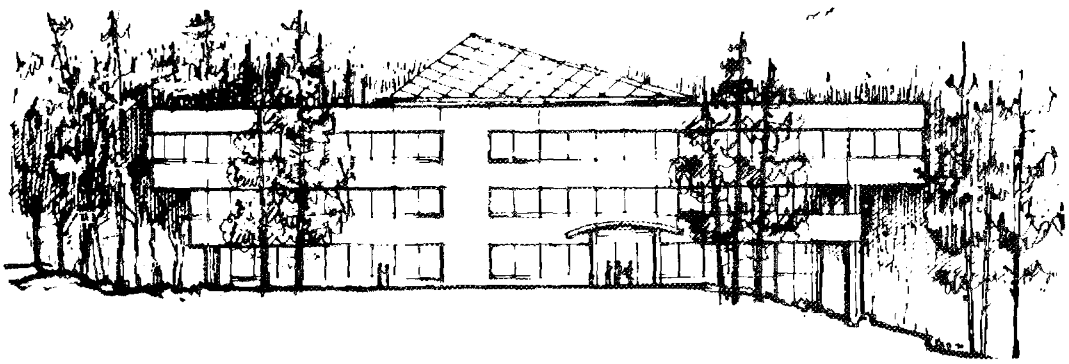


Figure 4.5 Conceptual drawing of the Center for Study of Advanced Materials

engineering that would reflect the special talents, facilities, and capabilities residing in the Southeast. These initiatives would address nationally significant problems that are important to both DOE and the university participants and that transcend the capabilities of a given institution. A proposal is being developed for the CSAM that would support the ongoing research and graduate education programs of the southeastern universities by providing a site at ORNL where students and faculty could be located while participating in joint research; by utilizing ORNL user facilities and staff; by holding workshops; and by otherwise benefiting from enhanced interaction with other university, industry, and national laboratory researchers. The center is intended to integrate and to enhance the entire spectrum of materials science and engineering opportunities at ORNL and to make them accessible to the southeastern institutions. The SURA communications network would be tied into the CSAM to provide scientific interchange through broadcasts of seminars, lecture series, workshops, and other significant technical presentations or discussions.

Operation of the CSAM would be carried out through the cooperation of SURA, ORAU, and ORNL. In preparation for the CSAM, an informal summer program was started at ORNL in 1989 for faculty and graduate students from southeastern universities.The program is now supported by DOE. Support for the CSAM is envisioned as joint funding from DOE-BES, the National Science Foundation (NSF) Division of Materials Research, state funds from the participating universities, and industry partnerships. Establishment of the CSAM would involve construction of a building adjacent to ORNL at an approximate cost of $17 million; operating costs are projected at $4 million to $5 million per year. Table 4.3 provides budget projections.

Solid State Research and Processing Science Center

The Solid State Research and Processing Science Center will allow the research activities that are now located in 15 separate buildings to be consolidated into a central facility as part of the MS&E Complex (Fig. 4.6). The 80,000-ft^2 building will provide about

Table 4.3
Budget projections by fiscal year for the Center for Study of Advanced Materials
($ in millions—BA)

	1993	1994	1995	1996	1997	1998
Operating expense	2.0	3.0	4.0	4.5	4.5	5.0
Capital equipment	2.0	0.5	0.5	0.5	0.5	0.5
Line-item construction	0	0	0	2.0	8.0	7.0

100 offices and 40 laboratories for state-of-the-art materials R&D. The new facility will replace aging facilities that cannot be upgraded to accommodate modern research or to

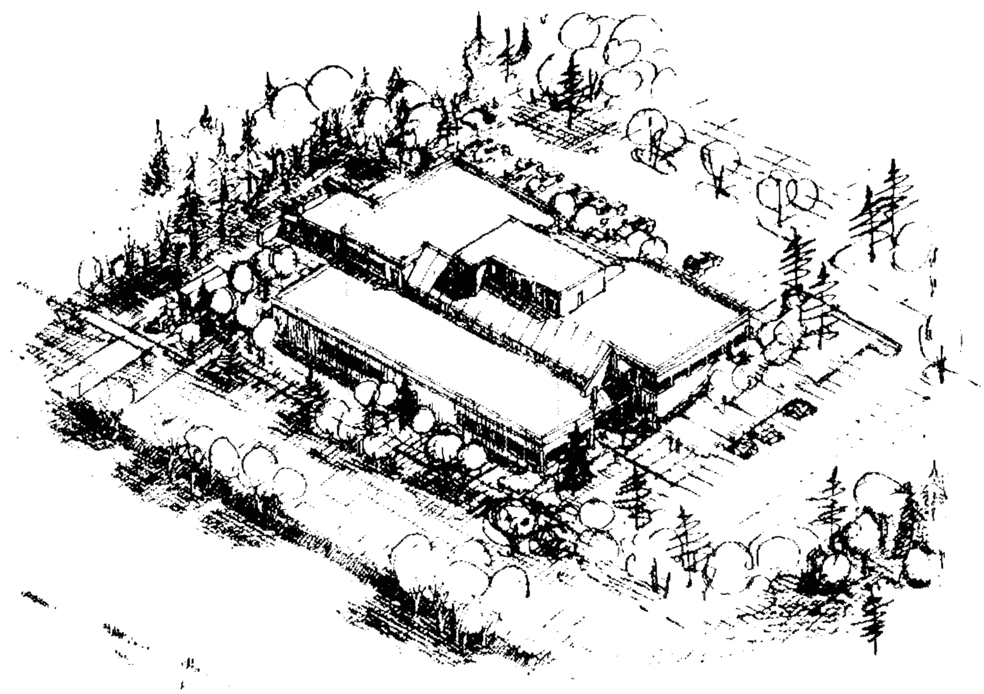


Figure 4.6
Conceptual drawing of the Solid State Research and Processing Science Center

comply with ES&H standards at acceptable costs, and it will enhance the effectiveness of the solid-state research program as part of the highly interactive MS&E Complex. Table 4.4 provides budget projections.

Table 4.4
Budget projections by fiscal year for the Solid State Research and Processing Science Center
($ in millions—BA)

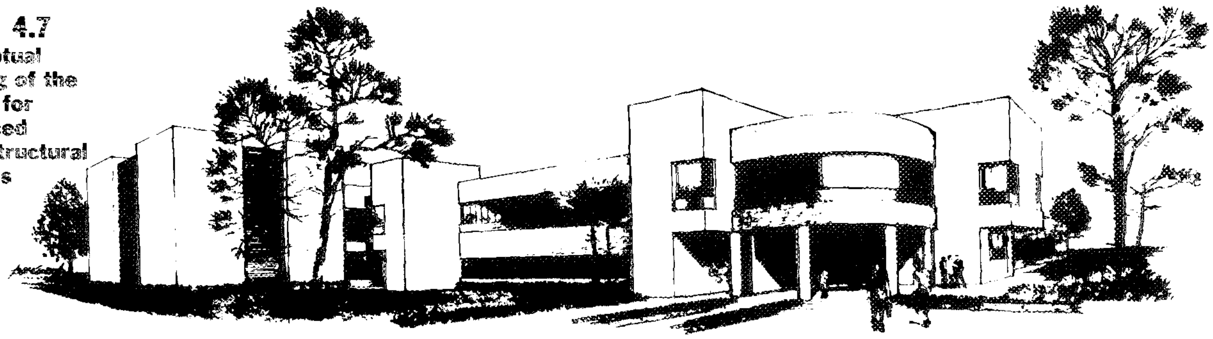
	1993	1994	1995	1996	1997	1998
Line-item construction	0	0	0	0	*a*	*a*

[a]To be determined.

Center for Advanced Microstructural Analysis

The CAMA will be a national resource for the user community (Fig. 4.7). As microanalytical instrumentation becomes more sensitive, performance is limited not by the instruments themselves but by the environment in which they are situated.

Figure 4.7
Conceptual drawing of the Center for Advanced Microstructural Analysis



Electromagnetic fields, building vibrations, and even low acoustic noise act to degrade performance. When most existing facilities were designed as general-purpose laboratories, little attention was paid to the environmental issues that now restrict performance. The CAMA will provide a state-of-the-art site for location of the broad range of microanalytical instrumentation available at ORNL, including analytical and high-resolution electron microscopes, atom probes and field-ion microscopes, surface analysis instrumentation, X-ray diffraction facilities, and mechanical property microprobes. Building services and even traffic patterns will be routed to enhance the isolation of the most sensitive instruments. The design of the 52,000 ft^2 building will emphasize information management and allow for digital-image acquisition and processing. Provisions will be made for remote operation of many of the most sensitive instruments. Integrated facilities such as these, which contain a concentration of state-of-the-art equipment and are available to a broad spectrum of outside users, will become essential to the future as the need grows and as the equipment becomes more complex and expensive. The cost is currently estimated at $41 million. The design will be started at the beginning of FY 1997; construction will be completed in FY 2000. Table 4.5 lists budget projections.

Table 4.5
Budget projections by fiscal year for the Center for Advanced Microstructural Analysis
($ in millions—BA)

	1993	1994	1995	1996	1997	1998
Capital equipment	0.5	1	2	1.5	1.0	*a*
Line-item construction	0	0	0	*a*	*a*	*a*

[a]To be determined.

Composite Materials Laboratory

The Composite Materials Laboratory will build upon ORNL work on polymer, carbon-carbon, and metal and ceramic matrix composites that are found in several different organizations (Fig. 4.8). The principal ORNL divisions involved with composites are the

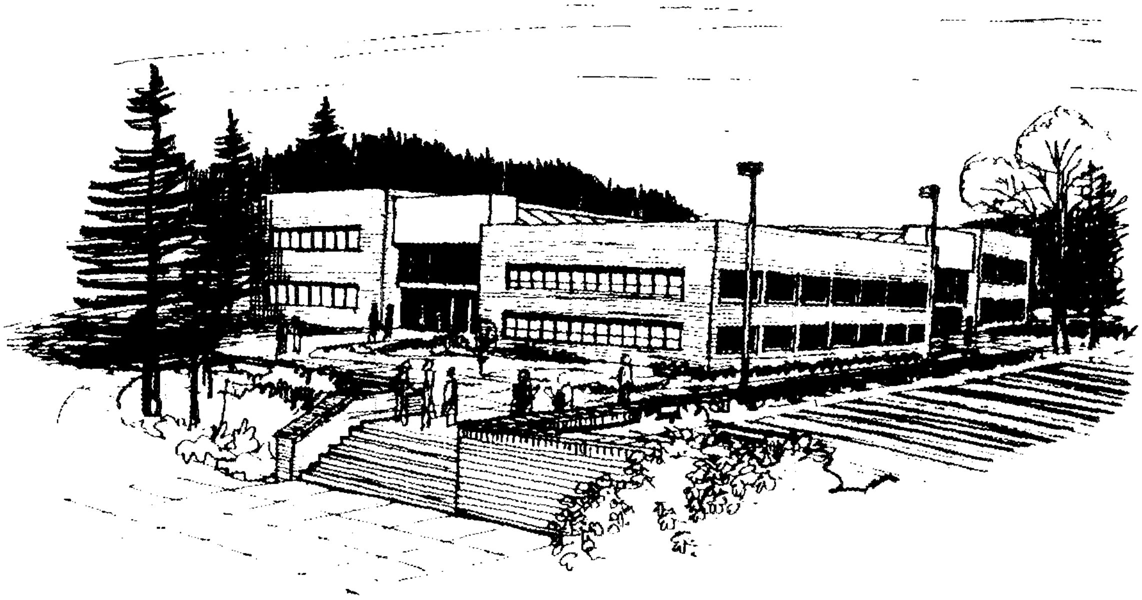


Figure 4.8 Conceptual drawing of the Composite Materials Laboratory

Applied Technology Division (ATD), the Engineering Technology Division, and the Metals and Ceramics Division. Other Energy Systems divisions with supportive specialties such as nondestructive evaluation and materials characterization are also expected to participate, and UTK will also contribute. The Center of Excellence for Materials Processing is the focal point for the composites research at UTK. The university departments involved in the composite research include Materials Science; Engineering Science and Mechanics; Mechanical, Aerospace, and Chemical Engineering; Chemistry; and Physics.

Composites R&D involves several technology areas: materials science and processing, mechanics, and prototypic fabrication and evaluation including nondestructive examination, manufacturing development and testing, and technology transfer. Materials science and processing focus on properties of engineering materials appropriate for applications by controlling composition, molecular structure and microstructure, and process variables. ORNL and UTK have a unique R&D capability for analyzing the mechanical behavior of composite structures through a predictive failure theory based on concepts of fracture mechanics and basic thermodynamic principles, environmental effects, and ORNL's extensive applied mechanics capabilities with attendant large-scale computing support. This collective capability can relate microstructural properties to structural performance. Critical to the use of composites is the ability to detect and to measure the size of defects by nondestructive examination—an area in which ORNL's experience in the examination of composites using ultrasonics and penetrating radiation (primarily X rays) will be invaluable. State-of-the-art X-ray computer tomography equipment and a digital image analyzer for radiographs have significantly enhanced the capabilities of ORNL to evaluate composite materials. The Composite Materials Laboratory is planned as a 50,000 ft^2 building that will house an interdisciplinary team of more than 100 ORNL and university scientists, engineers, students, and supporting staff. Table 4.6 lists budget projections.

Office of Guest and User Interactions

The OGUI is the ORNL interface with a large community of guests and users. The OGUI facilitates guest and user access to collaborative research facilities at ORNL by disseminating information about designated user facilities; identifying user facilities and other opportunities for collaborative research; providing assistance with the access and approval procedures that visits to ORNL require; negotiating legal agreements on research interactions; and assisting visitors with housing, transportation, and other support. The

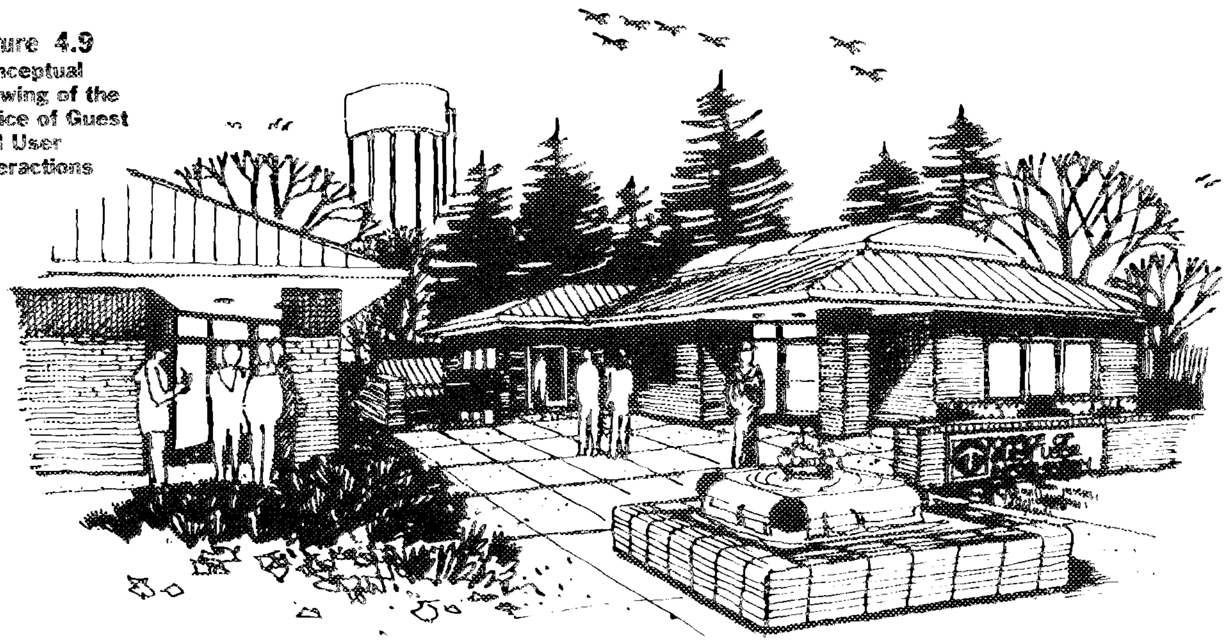
Table 4.6
Budget projections by fiscal year for the Composite Materials Laboratory
($ in millions—BA)

	1993	1994	1995	1996	1997	1998
Operating expense	8.0	10.0	11.0	12.0	13.0	*a*
Capital equipment	0.2	0.5	1.0	0.4	0.5	*a*
Total	**8.2**	**10.5**	**12.0**	**12.4**	**13.5**	***a***
Line-item construction	0	0	0	0	*a*	*a*

[a]To be determined.

OGUI is also responsible for coordinating all CRADA agreements initiated at ORNL. The OGUI supports 11 ORNL user facilities that have become important components of the DOE-ORNL mission. The user facilities satisfy national R&D needs, broaden the ORNL research base, and leverage the available funding. The OGUI handled more than 3600 visits in 1991 by scientists and engineers from universities, industries, and other federal laboratories. Despite its growing importance, the OGUI is currently housed in temporary trailers. A permanent building of about 6900 ft^2 (to be constructed at a cost of about $1.2 million) is proposed as an FY 1993 GPP (Fig. 4.9).

Figure 4.9
Conceptual drawing of the Office of Guest and User Interactions



Center for Computational Sciences

High-speed, large-scale computation has become the primary enabling technology for advanced research in many areas of science and engineering. Because of physical constraints and/or costs, computer simulations are the only feasible manner in which detailed research investigations on many complex phenomena can be performed. The number of investigations requiring such computer experimentation is rapidly increasing as scientists probe deeper into the understanding of both small and large systems (subatomic particles and the earth's climate, respectively). Thus computation has become an equal partner with theory and experiment in advancing the frontiers of knowledge. The exploitation of massive parallelism is expected to bring the next major increment in computational capacity that will be necessary for attacking the "grand challenges" of computational science. The solutions to these fundamental problems are of great importance to science and engineering but will require breakthroughs in computer architectures and algorithms and in how these can be brought to bear on specific applications.

To address these issues, ORNL has established a Center for Computational Sciences (CCS) to provide leadership and support for computational science activities at ORNL. The primary initial funding for this center is through the federal High Performance Computing and Communication Program. The vehicle for ORNL participation in this program is the Partnership in Computational Science (PICS). ORNL is joined in this partnership by Ames Laboratory; Brookhaven National Laboratory; Sandia National Laboratories, Albuquerque; Rice University; State University of New York, Stony Brook; Texas A&M University; the University of South Carolina; UTK; and Vanderbilt University. The partnership's proposal has been accepted by DOE, and ORNL has been named as one of two DOE high-performance computing research centers (HPCRCs). The other center is located at the Los Alamos National Laboratory (LANL). The CCS will manage ORNL's center.

The director of the CCS will initially report to the ORNL associate director for Physical Sciences and Advanced Materials. ORNL anticipates that computing activities could grow during the next few years to become a directorate for computing that would include responsibility for the CCS as well as other computing research and service activities. The CCS will include several components:

- grand challenge research,
- supporting mathematics and computer science research,
- a program for high-performance computing access for high school students, and
- state-of-the-art parallel computing systems to support the other objectives.

The two grand challenges selected for initial research by CCS through the partnership are groundwater transport in environmental modeling and remediation and first principles simulation of materials properties. These two problems satisfy the following basic criteria for selection:

- The problem is of fundamental importance, and its solution would be of great value to society or to science.
- For adequate accuracy and resolution, the problem requires computational power well beyond the capacity of today's supercomputers.
- The problem is amenable to the effective exploitation of massive parallelism.
- ORNL, together with its partner institutions, is in a position to make significant progress on the problem.

As a multipurpose national laboratory, ORNL has several other research problems that satisfy these criteria, such as global climate modeling, design and analysis of particle detectors for the SSC, fusion energy modeling, and fundamental problems in chemistry and biology. Grand challenge problems and research partners will be added in the initiative as long as sufficient resources are available.

ORNL already has in place the core personnel to form interdisciplinary teams to carry out much of the research in the grand challenge projects. Expertise in parallel computing research exists in the Mathematical Sciences Section of the Engineering Physics and Mathematics Division as well as in other groups and divisions. ORNL also has many specialists in the particular applied disciplines that would be involved who already have the necessary interest and experience in large-scale computations, even in large-scale parallel computations.

ORNL's 128-processor Intel iPSC/860, peak rated at 7.6 gigaflops (64-bit arithmetic), was replaced in the summer of 1992 by a 512-processor Intel Sigma L35 prototype, peak rated at nearly 40 gigaflops. This computer will, in turn, be replaced in the summer of 1993 by a 2048-processor Intel Paragon 150 capable of over 153 gigaflops and containing over 2 gigabytes of distributed memory and over 600 gigabytes of internal disk storage. These computers will not be operated in traditional time-shared, multiple-user supercomputer fashion, but in "grand challenge mode." That is, individual users will be able to access the full power of the computer for extended periods of time to solve large-scale, numerically intensive computational problems. In addition to the two grand challenges mentioned above, these CCS computers will provide time for global climate simulations for the DOE Computer Hardware, Advanced Mathematics, and Model Physics (CHAMMP) Program.

These computers, which are expected to be the most powerful supercomputers in the world at the time of their delivery, are accessible by researchers across the nation through all major research networks, and plans exist to make them regionally available through a high-speed fiber-optic network. Through these same network connections, researchers involved in the initiative can access parallel computers at other national computer centers and research organizations.

In late FY 1991, a Kendall Square system was acquired with DOE funding. The CCS is currently evaluating the merit of Kendall Square systems for the problems at hand. Initial findings indicate great promise for the architecture.

Preliminary efforts on several grand challenge and smaller computational science problems have already begun under support from various DOE research programs. Pilot projects designed to gain a better fundamental understanding of high-temperature superconductors and lepton pair production in atomic physics have been implemented by interdisciplinary teams from the Engineering Physics and Mathematics, Metals and Ceramics, and Physics divisions of ORNL. A multidisciplinary collaboration involving ORNL, the National Center for Atmospheric Research (NCAR), and Argonne National Laboratory (ANL) has produced a parallel version of the Climate-Change Model (CCM2), NCAR's latest global climate model. Other projects have involved fusion energy calculations and detector simulations for the Superconducting Super Collider. In these projects excellent progress has been made in implementing real application codes on ORNL's Intel parallel supercomputer. One of these projects has resulted in the naming of three ORNL staff members as winners of the 1990 Gordon Bell Prize for best price-to-performance ratio in parallel processing. Their code computes the electronic structure of high-temperature superconductors and runs at 2.5 gigaflops on the Intel iPSC/860.

An objective of the Groundwater Transport in Environmental Modeling and Remediation Grand Challenge project is to develop and implement models and algorithms for use on large-scale parallel computers to predict more accurately the fate of contaminants in groundwater. By mathematically conceptualizing the processes that influence groundwater, the regulators, decision makers, scientists, and engineers gain a better understanding of the phenomena governing groundwater flow and transport of contaminants. The mathematical models are limited by computational power because the matrix equations produce thousands of unknowns that must be evaluated thousands of times. Without powerful solution techniques and extensive computer power, complex flow regimes and chemical problems cannot be modeled feasibly. For example, more realistic models of bioremediation can be developed on the parallel supercomputer. Flow, transport, and biodegradation are addressed in current models. With the supercomputer, many additional processes can be included: additional biodegradation mechanisms, microbial transport, kinetics, small-scale processes requiring mesh refinement, permeability alteration by biomatter, fracture flow, multiphase flow, coupled geochemistry, and three-dimensional flow fields.

The long-range objective is to develop and validate a three-dimensional flow-and-transport model with the capability to accommodate biodegradation, multiphase and unsaturated flow; fracture flow; geochemistry; and solute and colloid/microbe transport. The planned ORNL software will be based on finite volume techniques on unstructured three-dimensional grids and will handle fractured media. Algorithms for mapping the grid system to the parallel computer, solutions to the resulting system of equations on the parallel computer, and visualization of the results are parts of the objective. The model will be used to study site parameterization through inverse problems and geostatistics, perform sensitivity analysis, study scale-up issues, and determine optimal remediation strategies.

The long-range objectives of the First-Principles Simulation of Materials Properties Grand Challenge are to model materials properties using first-principles theory (based on quantum mechanics and statistical mechanics) and to use these models to obtain fundamental understanding of materials to aid in the design of materials. The need for a powerful parallel supercomputer is based on the need to model systems consisting of thousands of atoms. Current technology limits models to tens of atoms. As the number of atoms increases, the quantum mechanical calculations scale up as the cube of the number of atoms. Similarly, the statistical-mechanics computations required to follow the motion of the atoms scale up as the cube of the number of atoms.

The plan is to port existing electronic-structure and molecular-dynamics methods to parallel architectures and to develop new methods for large systems. The features of the new methods will include real-space multiple-scattering theory, tight-binding molecular dynamics, and Car-Parrinello molecular dynamics.

The projects described above and other projects requiring parallel supercomputers will generate voluminous output. To comprehend this output will require turning the output into rich three-dimensional models and dramatic animations. The insight provided by "seeing" data in simulated images will lead scientists to new discoveries. By combining the power of scientific visualization with parallel supercomputers, scientists will be able to interact with the output, interpret what is happening in real time, and steer the computation to pursue interesting phenomena. The importance of the parallel super computer-visualization relationship is well understood at ORNL.

The plan for the visualization effort is to develop an Advanced Visualization Laboratory to provide participating scientists with visualization capability up to and including research in virtual reality. High-speed communication technologies will be employed to enable visualization activity to be done remotely from the parallel computer.

The last key component of the initiative addresses the current shortfall of computational scientists, engineers, and mathematicians being produced by our colleges and universities. The challenge of helping to meet this shortfall of human resources through supercomputing is an integral part of this initiative. Supercomputers can be used both as a magnet to draw students to science and engineering and as an enabling tool to assist in their understanding of technical matters. Initially, the CCS education effort will focus on the high school grades.

This element of the program is called Adventures in Supercomputing. In FY 1992, 20 high schools in Tennessee, Iowa, and New Mexico (supported in turn by ORNL, Ames Laboratory, and Sandia National Laboratories) are participating. Each high school sends a team of two teachers to participate in an intensive Summer Institute. Each school is lent four personal computing systems and provided with network access. During the school year, the teachers utilize these elements to allow their students to develop applications on laboratory-based systems. In particular, nCUBE has provided an 8-processor system that will allow advanced students to start to learn about parallel processing. Students will also work on a workstation that is the front end for the nCUBE and will have access to the National Education Supercomputer in Livermore.

An important element of the Adventures in Supercomputing Program is assessment. Objective measures of the progress of the program will be tracked to allow the value of the program to be measured as well as to provide guidance for improving the program as it evolves. In subsequent years, the program will be expanded to a wider geographic region and into lower grades.

Significant expansion of the leadership that ORNL has achieved in parallel computing is expected in the initiative. Interdisciplinary, interagency teams of senior scientists will be augmented by postdoctorates, graduate students, and distinguished visitors. New high-performance "early production" parallel supercomputers will be procured as they become available and will significantly add to the capabilities of the initiative. Connections to new high-speed national research networks will be pursued. A new building to house the various components and to provide a central location for the initiative's diverse activities will also be sought.

A number of studies and reports by distinguished panels of experts have recognized the critical importance of large-scale computation to the scientific and economic competitiveness of the United States. A number of federal funding agencies, including DOE, have established or plan to establish centers for intensive research in this area. Many computing companies, including Intel Scientific Computers, Inc.; Kendall Square Research

Corporation; IBM; Cray Researchers, Inc.; Thinking Machine Company; and nCUBE (as well as industrial firms interested in the grand challenge areas) have expressed interest in joining such a computational science initiative. All of these agencies, firms, and institutions will be given the opportunity to participate in the activities of the center.

Total budget projections for this initiative, which include PICS and other grand challenge efforts at ORNL, are provided in Table 4.7. Acquisition of large computer equipment will likely be purchased under a lease-to-own arrangement with operating funds.

Table 4.7

Budget projections by fiscal year for the Center for Computational Sciences Initiative[a]

($ in millions—BA)

	1993	1994	1995	1996	1997	1998
Operating expense	15.0	20.0	30.0	40.0	43.0	48.0
Capital equipment	1.0	1.5	2.0	3.0	4.0	4.5

[a]Funding for this initiative is being sought from the Office of Energy Research.

Advanced Materials, Design Methods, and Manufacturing Technology

Events of the past several years increase the urgent need of U.S. industry to become globally competitive. To realize this goal, it is critical that technologies related to product manufacturing be emphasized in an integrated approach. Figure 4.10 graphically displays the opportunities possible individually and collectively by integration of these three major disciplines (materials, design methods, and manufacturing technology).

With leadership from ORNL through this initiative, increased collaboration among industry, academia, and government will be stimulated, and national economic growth will receive an added boost.

Design methods, high-performance materials and processing, and advanced manufacturing technologies are key elements in the product development cycle, and they should be addressed in series. ORNL can make a significant contribution by addressing these issues concurrently and by combining and focusing the widely varying disciplines of the Laboratory. ORNL's background in the development and validation of high-temperature structural design and fracture mechanics methods coupled with high-temperature materials development and characterization, intelligent in-and-on process controls, and manufacturing technologies will be key elements of this initiative. As a federal laboratory, emphasis will focus on (1) improved performance and quality; (2) rapid transition of concepts, technologies, and materials into high-benefit products; and (3) the total product life cycle and associated environmental impacts.

A triad of activities usually must be included to develop products successfully that use advanced materials: (1) material science, (2) design methods and structural integrity validation, and (3) manufacturing science and technology. ORNL has a demonstrated track record in materials science, having introduced some of the most advanced ceramic composites, intermetallic alloys, polymer composites, carbon composites, and graphites. Goals of this major initiative are focused on (1) design methods and structural integrity and (2) manufacturing science and technology centers as an integral part of the MS&E Complex. Initiative efforts will emphasize products that impact energy consumption, production, and conservation in the transportation, aerospace, chemical-processing, and infrastructure markets.

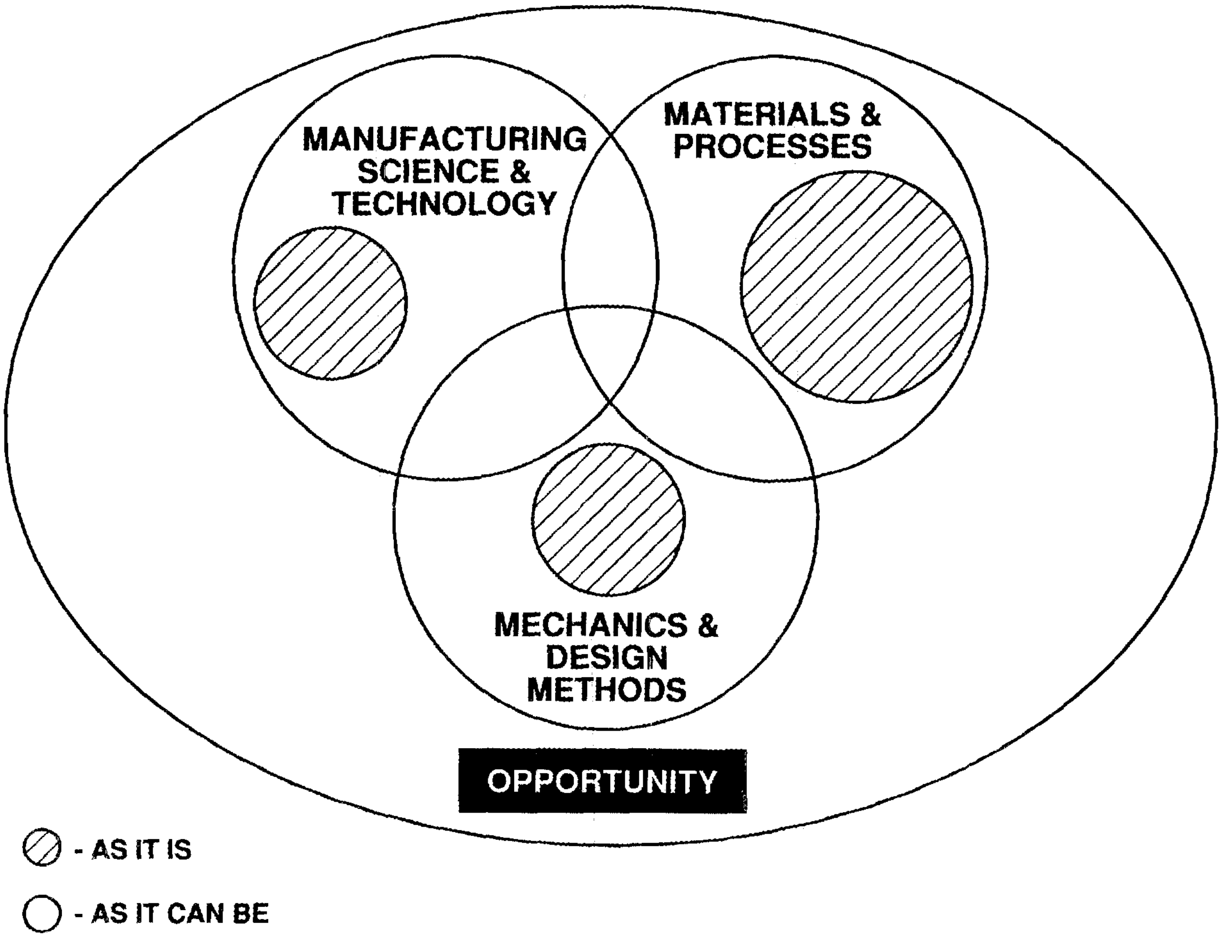


Figure 4.10 Because of its unique multidisciplinary nature, ORNL can develop an integrated approach to technological problems. Integration of the various disciplines at ORNL can improve U.S. global competitiveness and can create opportunities for collaborations with academia and industry.

As one part of this initiative a Design Methods and Structural Integrity Center for Advanced Materials will be established; its primary mission will be the development of appropriate design and fracture assessment methodologies for emerging advanced materials, thus accelerating their application and transfer to U.S. industry. While the center would primarily address high-temperature composite materials such as ceramics, carbons, intermetallics design, and composites (as shown in Figure 4.11), methods, fracture mechanics, and structural integrity validation for other high-usage materials such as concrete, metallics, and polymer composites would also be undertaken as appropriate.

The second part of the initiative will be the development of a Manufacturing and Processing Technology Integration Center (MAPTIC), which will focus on the science and processing technology for precision manufacturing of high-performance materials. Materials of interest would include metallics, ceramics, carbons, and composites. The programs of MAPTIC will develop, validate, and integrate emerging as well as enabling manufacturing and processing technologies that can be used to produce high-benefit components and systems while achieving the goals of affordability and endurability. Emphasis will be placed on producibility by means of an integrated team approach that will include designers, materials scientists, manufacturing engineers, and the users. The team will interact closely with the Design Methods and Structural Integrity Center and the CAMA. Design of and with materials must be done concurrently with manufacturing and process development. This is a Laboratory-wide initiative, and interdisciplinary teams will be established to support the rapid development and transition of innovative technologies into commercial realities. By the integration of activities of MAPTIC with other capabilities across the Laboratory, and with the newly created Manufacturing Technology Development Center at the Y-12 Plant, it is envisioned that the U.S. industrial base will be more rapidly invested with DOE technologies.

The activities of this initiative will involve several disciplines and divisions (including Metals and Ceramics, Applied Technology, Instrumentation and Controls, and Engineering Technology) and will emphasize networking across all of Energy Systems. Strategic relationships will be formed with universities, other national laboratories, government

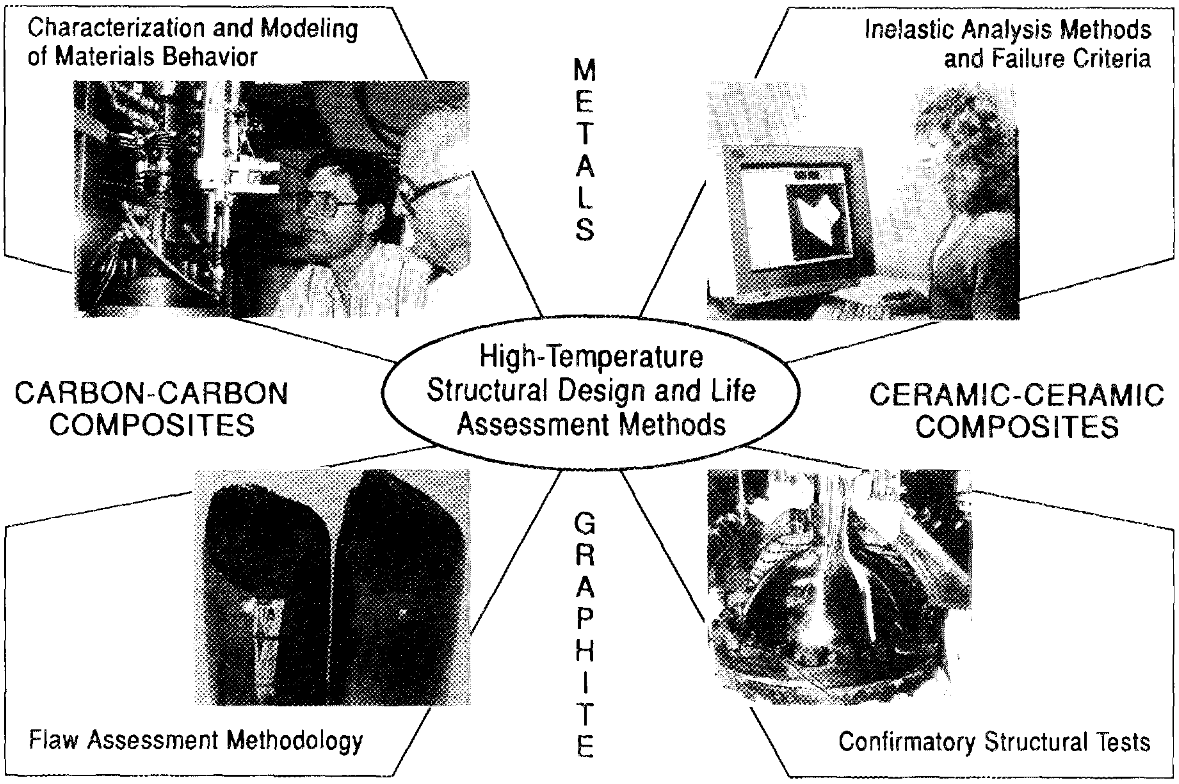


Figure 4.11 By developing fundamental structural mechanics, failure mechanisms, and design methods, products and systems can be more effectively designed for application and manufacturing.

agencies, industries, and industrial consortia such as the National Center for Manufacturing Science (NCMS) and the Association for Manufacturing Technology.

The vision for MAPTIC is that it will be recognized as a premier facility for developing, demonstrating, and validating manufacturing science and technology that provides our nation's manufacturers with real and sustaining competitive advantages in global markets. All programs will have the common objectives of enhanced system performance through the concurrent development of cost-effective designs and safe, environmentally responsible manufacturing and processing technologies.

As the Manufacturing Technology Deployment Center of the Y-12 Plant becomes more accessible, industry and academic partners will participate in building the MAPTIC concept through CRADAs and exchange of personnel. Advanced manufacturing cells for a broad variety of technologies will emerge in both existing buildings and in a new center requested for 1996. Table 4.8 lists the budget projections for the total initiative.

Transportation Technologies and Systems

Transportation consumes two-thirds of the oil used by the United States. Thus the transportation sector offers the most important opportunity to reduce U.S. dependence on oil imports. Air quality in most large urban areas is below minimum health standards, largely because of automobile and truck emissions.

Transportation is a vital component of U.S. industry. The domestic auto industry is the largest segment of manufacturing, accounting for one out of every seven jobs in America. The industry is on an uneven playing field, with global competitors producing out of newer plants, using newer equipment, and enjoying government R&D support. Regaining the lead in automotive production will require a new era of teamwork in this country between government and industry.

Investments in transportation infrastructure have not kept pace with the nation's needs for mobility, economy, and safety. While our system is still the best in the world,

Table 4.8

Budget projections by fiscal year for the Advanced Materials, Design Methods, and Manufacturing Technologies Initiative

($ in millions—BA)

	1993	1994	1995	1996	1997	1998
DOE funding[a]	4.0	7.5	1.8	34.0	32.0	40.0
Non-DOE funding[b]	3.5	7.0	1.5	20.0	32.0	40.0
Total	**7.5**	**14.5**	**33.0**	**54.0**	**64.0**	**80.0**
Operating expense	7.0	13.5	31.0	42.0	60.0	76.0
Capital equipment	0.5	1.0	2.0	2.0	4.0	4.0
Line-item construction	0	0	0	10.0	0	0

[a]DOE programs DP, CE, ER, and NE.
[b]Non-DOE: NASA, DOD, and industry.

congestion problems now threaten this mobility. The Federal Highway Administration (FHWA) estimates that delays from congestion alone result in losses of $100 billion annually. The Intermodal Surface Transportation Efficiency Act of 1991 signals a much-needed and wide-reaching attack on these problems. In its policy statement, the act says,

> It is the policy of the United States to develop a National Intermodal Transportation System that is economically efficient and environmentally sound, and will move people and goods in an energy efficient manner.

DOE and other federal agencies have recognized these challenges. The 1992 update of the National Energy Strategy cites numerous federal transportation initiatives and points out that the total federal R&D funding on transportation requested for FY 1993 is 39% above FY 1992 and 76% above FY 1991. Notable R&D initiatives are the $260 million joint research venture on advanced batteries with a consortium of automakers and a proposed $20 million start on a similar program to develop hybrid vehicle propulsion.

Our discussions with the automakers have revealed a striking shift in attitudes: collaboration with national laboratories is now a top priority. General Motors executives visited Oak Ridge in June 1991 and visited the other national laboratories during the summer. Numerous exchange visits of technical personnel have served to identify specific topics of mutual interest. Discussions with Ford and Chrysler have shown that they are pursuing similar ideas.

Our goal is to secure a major share of the DOE resources that are identified for collaboration with industry on automotive programs. Since some of the transportation research responsibility lies outside the DOE charter, we will seek to broaden our activities by expanding our participation in DOT and DOD programs. We intend to work in close collaboration with the Y-12 Plant in areas such as hybrid vehicle technology, materials and processing, low-emission vehicles, and advanced production processes that address the goal of "agile manufacturing systems."

ORNL is in a strong position to undertake important research assignments on transportation. We have widely recognized strengths in many vital disciplines. Our materials capabilities are among the best in the country. We have managed the Ceramic Technology Project for the DOE Office of Transportation Technologies since 1983. We have worked with the automotive industry on applications of intermetallics. We have a background in fabricating high-strength polymer composites, derived from the uranium enrichment program. The HTML serves as a unique facility for joint laboratory-industry materials research. We have worked with the automotive industry on topics of fuel composition, combustion, and catalysis related to alternative fuels since 1984 and have conducted fleet evaluations of both electric and methanol fuel vehicles. We are working with the Motor Vehicle Manufacturing Association on nonchlorofluorocarbon (CFC) refrigerants for mobile air conditioners.

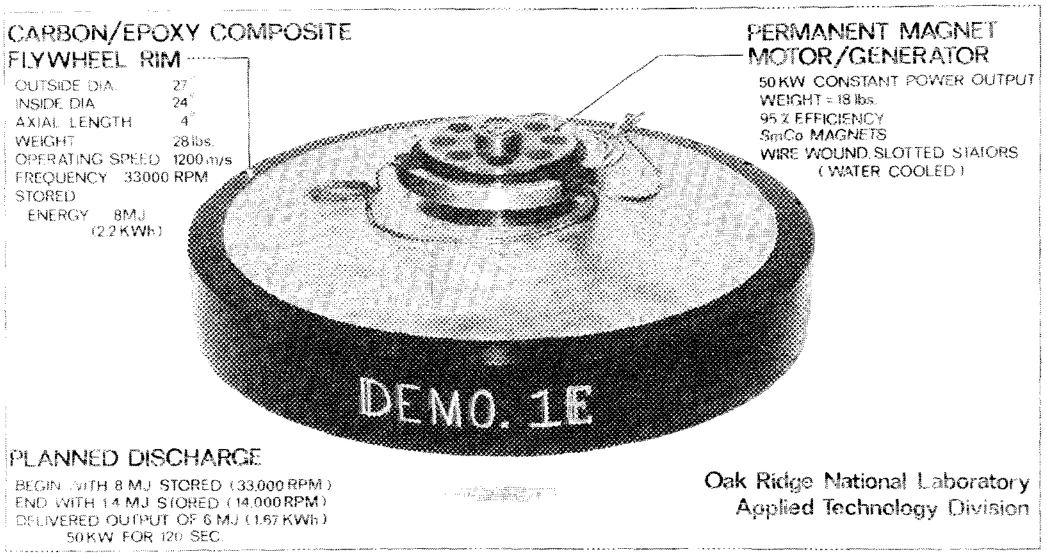
In our Center for Transportation Analysis we have provided analytical support to the DOE Office of Transportation Technologies and the Office of Policy, Planning, and Analysis during the past 15 years. We perform analyses of motor vehicle fuel economy, sales, and technology and assist with program planning. Results are published in the annual *Transportation Energy Data Book*. This work has expanded into support of the DOT's national highway and intermodal planning activities and support of the national defense transportation missions of the DOD. For example, ORNL is recognized by both agencies as the only authoritative source of national transportation network data bases.

Our technology transfer program has been widely noted and emulated. We have moved aggressively to license our R&D results for application by industry. We were among the first to utilize the CRADA mechanism to work with industry. And we have shown that we can respond to industry's needs by establishing CRADAs in just a few weeks' time to meet requirements for rapid action.

The following elements of an expanded program utilize strong ORNL capabilities and have a high priority in both industry and DOE.

- **Hybrid electric vehicle.** The Secretary of Energy recently commented that the hybrid vehicle initiative is one of the most exciting opportunities on the horizon. This concept will have some combination of electric vehicle components and conventional or turbine engine with battery or flywheel storage. ORNL participation could include development of propulsion systems, permanent magnet motor/generator, regenerative braking, power electronics and controllers, flywheels, and advanced magnetic materials. Flywheels are an important alternative to batteries for energy storage in vehicles. They have already achieved specific energy storage equaling the goal for batteries, have a lifetime exceeding the life of the vehicle, and do not contain hazardous materials. Technology demonstrated at ORNL is shown in Fig. 4.12. Much of the lightweight materials activity described below would have application in hybrid electric vehicles.
- **Vehicle emissions reduction.** Important needs include both sensors and catalyst materials, particularly for NO_x reduction. New instrumentation to measure trace gas concentrations in the atmosphere at useful measurement scales is another research objective.
- **Lightweight materials.** Vehicles of the future will need to take advantage of weight reduction through use of high-strength low-alloy steels, aluminum and magnesium

Figure 4.12 Integrated flywheel motor/ generator developed at ORNL



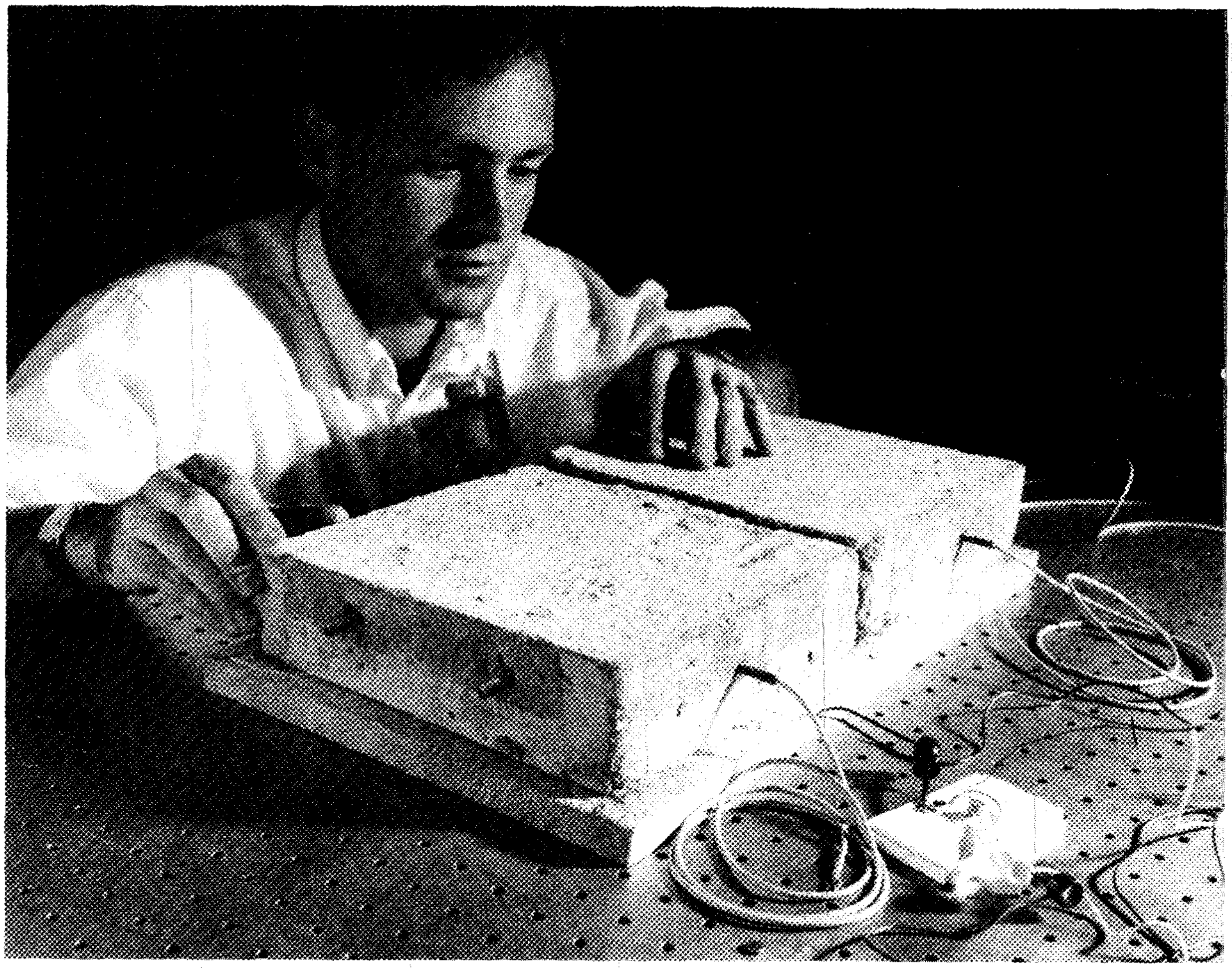
alloys, metal-matrix composites, and polymer composites for body panels, chassis structural components, and power-train components.

- **Intelligent vehicles and highways.** Advanced computing, communication, and control technologies are needed to cope with energy-wasting traffic congestion. Prospective ORNL research includes work on crash-avoidance systems, measurement of vehicle energy efficiency and emissions, vehicle guidance and control, vehicle and driver diagnostics, traffic control simulation, advanced traffic control centers, human factors in system design, fast computing and application-specific integrated circuits, dynamic route planning, and system evaluation methodologies. ORNL is leading efforts to develop a regional consortium to conduct and evaluate operational tests of advanced vehicle and highway technologies, which could lead to operation of a national user facility.
- **Agile manufacturing.** This concept encompasses manufacturing systems such as concurrent simulation and engineering, process certification, net-shape processing, and universal machining.

The following additional areas of transportation systems research make use of demonstrated ORNL capabilities and are expected to be of interest to DOT, DOD, and other government agencies.

- **Infrastructure modernization.** These tasks would apply ORNL expertise in structural engineering and materials science to the problems of premature deterioration of pavements and bridges. Recently, ORNL researchers have embedded miniature fiber-optic sensors in a number of materials, including concrete and asphalt (Fig. 4.13). Such sensors could be used to detect and evaluate incipient deterioration of highways and bridges. They could also serve as part of the diagnostic network for "smart highway" functions. ORNL leadership of a national consortium to track bridge performance and to conduct related research is envisioned.

Figure 4.13 Fiber-optic sensors imbedded in concrete slabs provide information about internal stress.



- **Transportation demand management.** As urban and highway congestion worsens, it will be increasingly necessary for communities to apply to transportation the kind of integrated resource planning that has been successfully used by electric utilities to optimize electrical end-use demand.
- **Military transportation.** ORNL made important contributions to military transportation planning and scheduling during the Persian Gulf crisis. The nation's new defense posture means that much additional research is needed on planning and scheduling military systems to meet the requirements of the rapidly evolving world geopolitical system.
- **Hazardous materials.** ORNL capabilities and experience in packaging and transporting hazardous materials can be applied to a wide range of problems related to shipping dangerous goods.

Baseline projections for the initiative are indicated in Table 4.9. The projections include continuation of existing ORNL transportation programs (about $22.8 million in FY 1992) but do not include the industry portions of joint projects or the portions of the projects that we expect to be done by the Y-12 Plant.

Table 4.9
Budget projections by fiscal year for the Transportation Technologies and Systems Initiative[a]
($ in millions—BA)

	1993	1994	1995	1996	1997	1998
Operating expense	30.5	40.1	48.6	54.0	60.0	70.0
Capital equipment	3.5	4.0	4.0	5.0	5.0	5.0

[a]Funds are being sought for this initiative under Program CE, Conservation and Renewable Energy.

Oak Ridge as a National Fusion Nuclear Site

We propose that a portion of the Oak Ridge Reservation be identified as the U.S. location for the nuclear facilities needed for development of the magnetic fusion energy program.

The fusion program is aimed at the development of fusion as an energy source. The National Energy Strategy, incorporating fusion as an energy program, has set the goal of a demonstration reactor by about the year 2025. Much of the development needed to achieve this goal relates to fusion nuclear technologies, yet the U.S. Fusion Program has no nuclear-capable site at which to conduct the necessary research. Oak Ridge is an ideal location for such a site because of the availability of an existing scientific and engineering infrastructure in fusion, materials, and nuclear processing, coupled with the availability of the required electrical power, cooling capability, and environmental characteristics. Furthermore, the communities in the Oak Ridge area have shown strong support for such initiatives in the past.

The current set of major tokamaks are coming to the end of their planned experimental programs. In the case of JET and the Tokamak Fusion Test Reactor (TFTR), they will demonstrate substantial levels of nuclear fusion power (tens of megawatts) for short pulses (seconds). Indeed JET has already produced about 2 MW of power in a preliminary experiment. Thus the nuclear technology development phase of fusion is upon us. Many of the major facilities planned for the future require a nuclear-capable site. These include a 14-MeV neutron source for fusion materials development; the next large tokamak, the International Thermonuclear Experimental Reactor (ITER) being planned as an international collaboration; and the proposed small devices for fusion nuclear technology development. None of the existing U.S. fusion facility sites can accommodate these devices. Our potential international partners—particularly the Europeans—have suitable sites identified. As an example, the French moved the bulk of their fusion effort from Fontenay-aux-Roses and Grenoble to Cadarache some years ago and now have a fusion infrastructure on a nuclear-qualified site suitable for ITER and other fusion nuclear facilities. The Oak Ridge Reservation offers a number of sites that could serve this purpose.

We would propose that DOE rapidly hold a competition to identify a suitable fusion development site, at which any major future capital investments would be made. This would give the United States a competitive position for the ITER as well as other facilities that might be proposed for international collaboration such as the 14-MeV neutron source. This initiative could be coupled with a proposal for operation and management of the site in a way that would involve more programmatic involvement by the private sector.

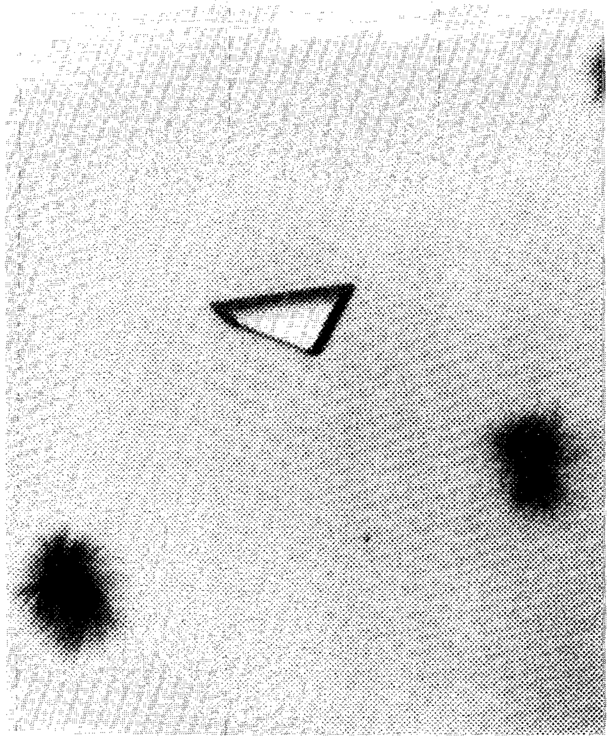
Structural Biology

In its broadest sense, the goal of structural biology is to understand the intricate relationship between biological structure and function. As such, it incorporates experimental techniques that derive three-dimensional structural information from the analysis of radiation in various segments of the electromagnetic spectrum that are scattered by biological materials. Paramount among scattering techniques in structural biology are X-ray and neutron small-angle scattering, crystallography, and several forms of biological imaging. Protein engineering is another important experimental tool in structural biology. Biotechnology, in the form of bioprocessing capability, and areas of computational biology support the scattering methods. This initiative combines ORNL strengths in these areas to address structural biology problems.

Protein engineering is an active program in the Biology Division and integrates many activities in molecular genetics. The ability to program specific mutations into cloned genes will permit the systematic design of new gene products as mechanistic probes of protein function and the tailoring of operons to alter the regulation of gene expression. X-ray and neutron structural analysis of crystallizable proteins and subsequent molecular modeling with three-dimensional computer graphics will guide the selection of mutant gene products to be constructed and will serve as a predictive tool of the probable structural consequences. Because protein engineering provides an avenue for optimizing functional properties of enzymes, it overlaps with other elements of biotechnology.

A core proposal that includes biological applications of small-angle neutron scattering, small-angle X-ray scattering, neutron and X-ray crystallography, and nuclear magnetic resonance (NMR) is under review by OHER. Macromolecular X-ray crystallography is being reestablished in the Biology Division. Proteins being studied for three-dimensional structure determination include phosphoribulokinase, human epidermal growth factor (EGF) (Fig. 4.14) and mutant analogs designed by ORNL's Protein Engineering Program, as well as human and mouse DNA repair proteins that remove alkylation lesions. Crystallographic studies of nucleosomes reconstituted from a cloned palindromic DNA restriction fragment are partially funded by OHER. As part of the revitalization of structural biology at ORNL, neutron and X-ray small-angle scattering, formerly components of the NSF-sponsored National Center for Small Angle Scattering Research, are being recommissioned under FY 1992 Laboratory-directed R&D funds that were awarded to a team of researchers from Biology and Solid State divisions. This program will also reactivate a neutron four-circle diffractometer at the HFIR for structural biology research. These activities will enhance structural biology research at these national resource facilities, pending core support from OHER, and will continue an ORNL program as the basis for developing a structural biology program at the ANS. The ANS will permit rapid, precise determination of biological structure by neutron scattering and crystallography; its potential to solve new biological problems will attract structural biologists worldwide (Fig 4.15).

Figure 4.14
Crystal of recombinant human epidermal growth factor



Computational biology involves the use of advanced computing devices and techniques for gathering and processing information on biological structures. It includes molecular visualization, rapid processing of macromolecular scattering data, prediction of molecular structure, and simulation of macromolecule behavior after chemical modification or changes in environmental influences. As such, this part of the initiative involves a number of divisions at ORNL, including Biology, Chemistry, Health and Safety Research, and Engineering Physics and Mathematics. High-performance computing in particular is well suited to studying these types of problems, and the new ORNL Center for High Performance Computing will serve as a valuable resource to the Structural Biology Initiative.

Biological imaging involves expertise concentrated in ORNL's Health and Safety Research Division (HASRD) and involves the use of a novel class of microscopes that have been identified as a cost-effective, high-volume technique for studying DNA. These microscopes work by scanning a tiny probe very near a surface onto which DNA molecules have been applied. AFM mechanically feels the the surface whereas the STM electrically feels the sample using a small electrical current. A third type of microscope, which was invented at ORNL, is the PSTM, which uses an optical current to a sharpened optical fiber to sense the sample. These instruments are new exploratory tools for visualizing biological structure at near-atomic resolution, and they have the potential for performing genome mapping and sequencing functions.

Budget projections for the Structural Biology Initiative are found in Table 4.10. Funding is being provided by OHER in the Office of Energy Research.

Biotechnology

Biotechnology for the twenty-first century is a new federal cross-cut initiative involving 12 agencies in biological and engineering research that will improve public health, enhance the quality of life, and contribute to economic growth. This presidential initiative developed by the Committee on Life Sciences and Health of the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET) is designed to maintain the momentum of U.S. leadership in health-directed biotechnology research and to encourage new applications in agriculture, energy, and the environment. The initiative calls for a supplement to the President's Fiscal Year 1993 Budget.

Biotechnology research at ORNL is conducted at various stages of biological organization, ranging from molecular through organismic and system levels, and addresses basic and applied research as well as bioprocessing development and appropriate socioeconomic issues.

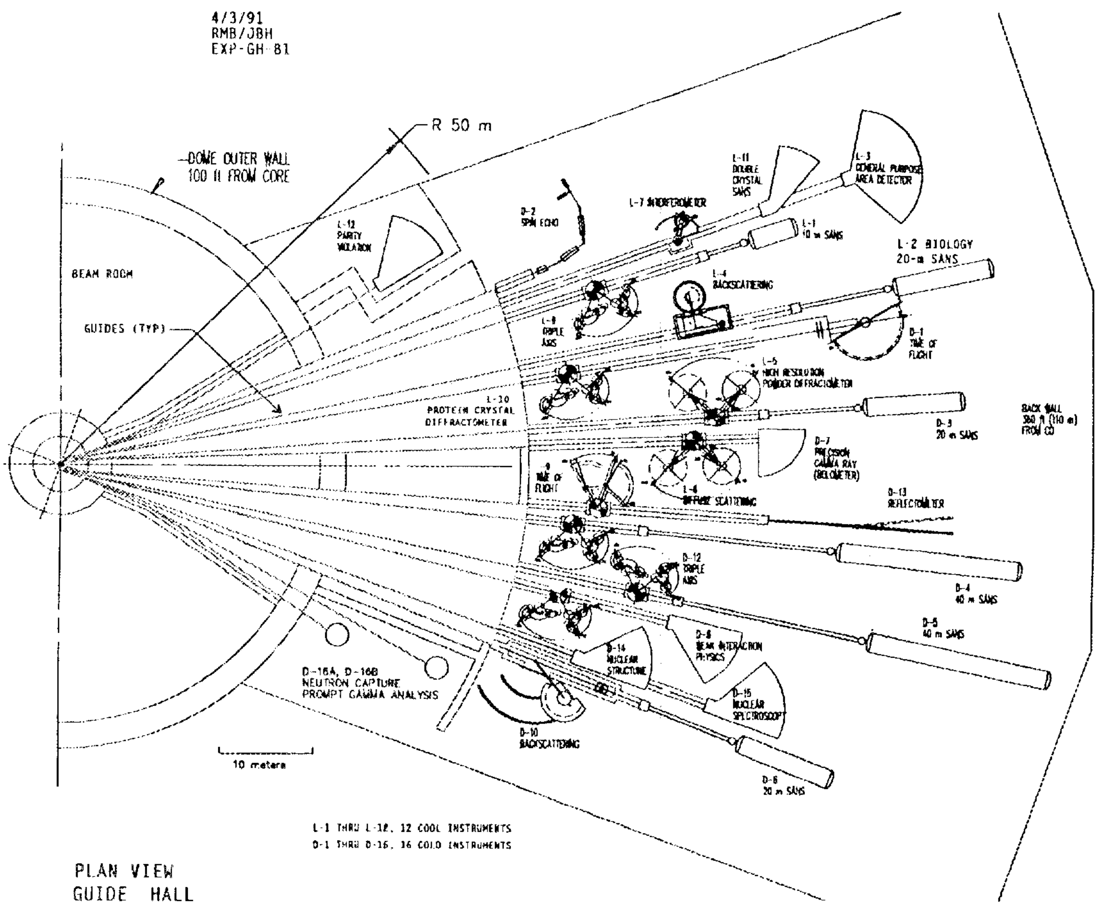


Figure 4.15
Sketch of the ANS guide hall, showing its array of instrumentation. Because of its potential for solving problems in structural biology, the ANS will attract researchers from around the world.

Table 4.10
Budget projections by fiscal year for the ANS/HFIR/ORNL Structural Biology Initiative
($ in millions—BA)

	1993	1994	1995	1996	1997	1998
Operating	2.7	2.7	2.8	3.4	3.4	3.6
Equipment	0.78	1.0				
ANS instrumentation[a]						5.0
ANS bio-facilities construction[b]						2.0

[a]Beginning in FY 1996 for detailed design with construction in FY 1998–1999.
[b]ANS Biology Laboratory detailed design beginning FY 1995 with construction in FY 1997–1999. Multipurpose (deuterium) Labeling Facility planned as part of the Center for Biological Sciences.

Fundamental research in biotechnology derives primarily from considerable expertise in cloning recombinant DNA, designing hybridoma cells, studying microbial ecology, and constructing transgenic mice. Cloning, in conjunction with manipulation of genes in vitro, has ushered in the era of protein engineering, whereby properties of proteins might be optimized for application in medicine, agriculture, waste remediation, and bioprocessing. Monoclonal antibodies, elicited by hybridoma cells, have wide-ranging applications, including the detection of physiological and xenobiotic molecules; they also can be used for the early detection and treatment of cancer. Transgenic mice, constructed by insertional or targeted mutagenesis, open new vistas for developing experimental models for human diseases and potentially for mitigating genetic disorders by gene therapy.

The design of new assays that can provide a basis for better assessments of human health risks of chemical carcinogens is imperative. New rapid advancements in the molecular biology of cancer are now providing a unique opportunity to design biotechnology-based assays. Recently, a new group of cellular genes, called tumor suppressor genes, have been discovered that are powerful inhibitors of cell growth. Single base-pair mutations or deletions in tumor suppressor genes are now recognized as the most frequent and critical events in tumorigenesis. Further, individuals with these mutations who have a risk to develop cancer can now be identified using biotechnology-based methods prior to cancer onset. Monoclonal antibody–based technologies can be used to design new assays to detect individuals with mutated tumor suppressor gene products (Fig. 4.16). Mutations or deletions in individuals at risk can also be detected using molecular biology/biotechnology–derived assays like polymerase chain reaction, followed by single strand conformation polymorphism or heteroduplex formation assays. These biotechnology-based techniques also can be used to design new in vitro assays to assess the carcinogenic potential of chemical carcinogens and to design new assays for promoters.

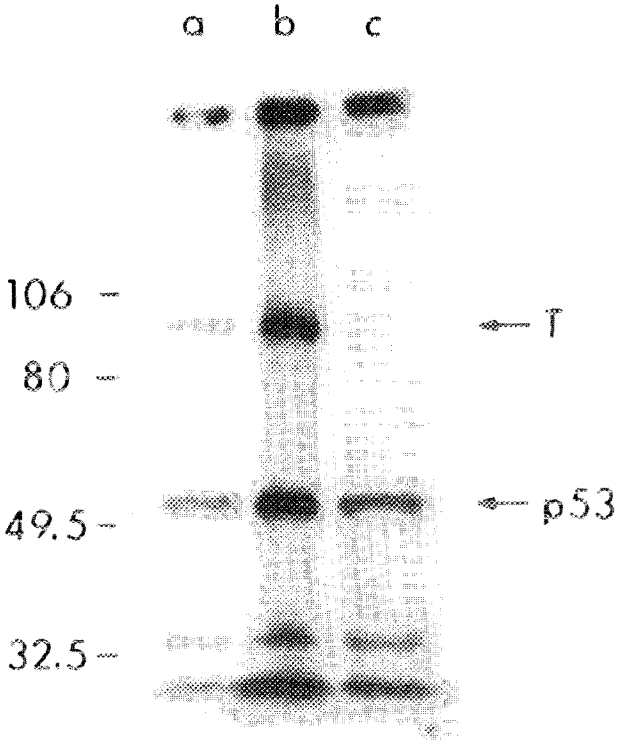


Figure 4.16 Biotechnology-derived anti-tumor suppressor gene monoclonal antibodies can be used to detect the effects of chemical carcinogens. Lane a contains the p53 phosphoprotein precipitated from cells not treated with the tetraphorbol ester (TPA) tumor promoter. Phosphorylation of p53 decreases when the cells are treated with a vitamin A analogue (retinoic acid), which reverses the effects of TPA. The same monoclonal antibody also can be used to detect the effects of tumor-causing viruses. The large T antigen is produced by a tumorigenic DNA virus.

Future work will be directed at (1) design of new in vitro assays to test the carcinogenic potential of chemicals associated with energy use and production; (2) design of new assays, using antitumor suppressor gene product monoclonal antibodies, to directly identify individuals at risk of cancer (leukemia) because of exposure to chemicals; and (3) use of antitumor suppressor gene monoclonal antibodies to evaluate risks of humans exposed to radiation during energy production.

Biotechnology also provides useful measurement techniques and is a component of the ORNL R&D effort. Differential labeling of DNA with stable isotopes has simplified sequencing activities, but efficient sequencing of DNA will require a new generation of instrumentation. One approach being evaluated involves using state-of-the-art laser and mass spectroscopy techniques. Scanning tunneling electron and photon microscopy is another high-tech probe being applied to biological materials.

Laser-induced surface-enhanced Raman techniques are used to provide vibrational and structural information on DNA, nucleotides, and proteins (Fig. 4.17). Biological markers are valuable tools for investigating recovery of systems following restoration and evaluating exposure potential to released contaminants. Development of useful biological markers involves interdisciplinary research spanning areas from molecular biology to analytical techniques. The application of biological markers to human exposures/disease states requires development of novel, ultrasensitive analytical strategies. DNA adducts in fish and mammals have been used to determine exposure of organisms to polyaromatic hydrocarbons. Elevated levels of mixed-function oxidase have been used to evaluate direct toxic effects, and the return of sensitive species to habitat has provided direct evidence of the success of restoration activities.

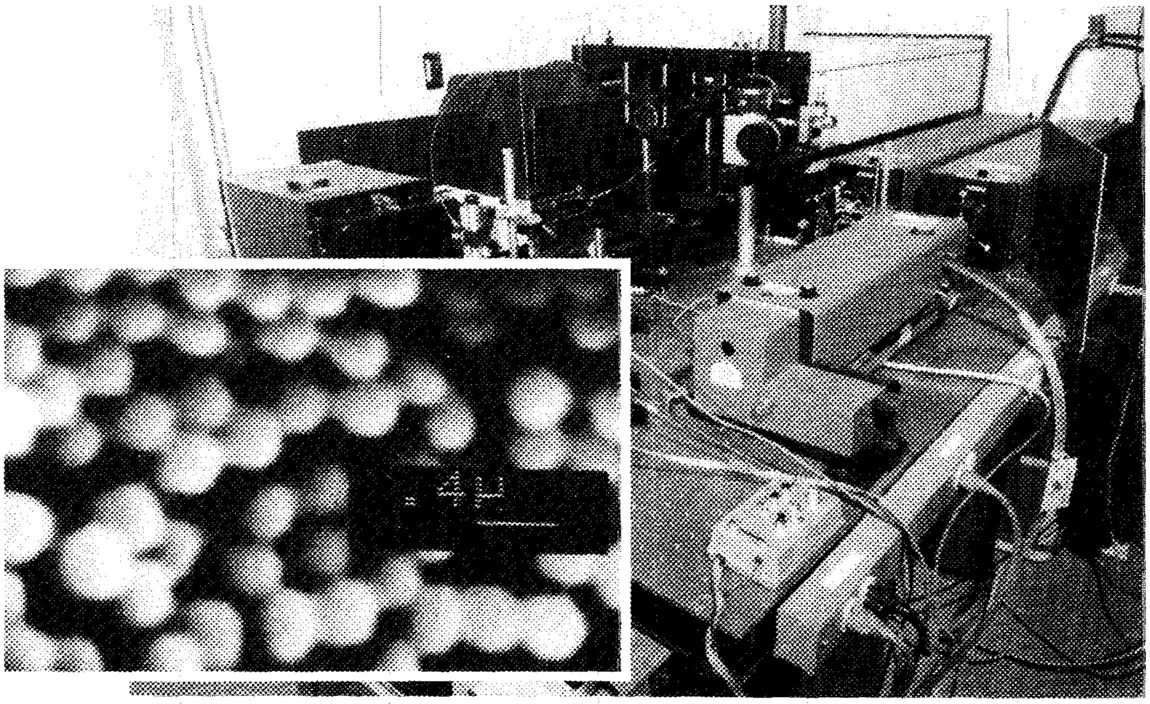


Figure 4.17 An experimental setup of the laser-induced surface-enhanced Raman spectroscopy (SERS) technique, which uses special microparticle-based substrates coated with silver (inset) to increase the Raman signal of adsorbed molecules and to provide vibrational and structural information on DNA, nucleotides, and proteins. SERS-based biosensors are also being developed at ORNL for monitoring biochemical species and biotechnology products.

Bioprocessing research is oriented toward the development of processing concepts and systems that can be used for energy production and conservation, conversion of renewable feedstocks, hazardous and radioactive waste processing, and the solution of other national problems. Bioprocessing R&D within ORNL is expanding with current support from various parts of DOE, other government agencies, and the industrial sector. Other prospects exist in conservation, fossil energy, energy research, and the Space Exploration and Space Technology initiatives, with significant potential for synergistic interactions. To maintain good coordination, encourage multidisciplinary interactions, and serve as a vehicle for further expansion, the Bioprocessing Research and Development Center was established in the fall of 1991 at ORNL. Furthermore, ORNL is one of four national laboratories participating in a consortium on bioprocessing R&D; Idaho National Engineering Laboratory (INEL), ANL, and the National Renewable Energy Laboratory are the other organizations collaborating in this effort under the terms of a memorandum of understanding. The Bioprocessing Research Facility (BRF) is available at ORNL for cooperative and proprietary research; industrial participation through CRADAs and other interactions is a primary focus of the program.

Applied biological research is carried out in support of bioprocessing concepts with an emphasis on photobiology, enzymology, and microbiology. Engineering research stresses advanced bioreactor concepts, enhanced biocatalyst systems, separation technology for product recovery and purification, and system monitoring and control. All areas of energy research have been addressed with bioprocessing developments in fossil energy, environmental control technology, production of fuels and chemicals from renewable sources (Fig. 4.18), nuclear and hazardous waste processing, CO_2 recycling, and resource recovery.

Development of technology for site remediation is also an important component of this research area. This has included fiber-

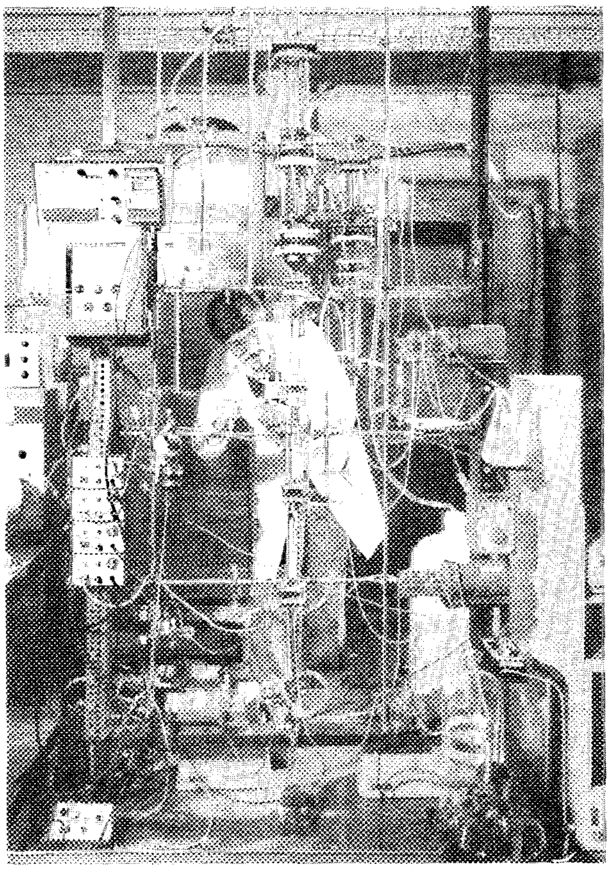


Figure 4.18
Advanced bioreactor systems such as this fluidized-bed system have been shown to increase productivity of ethanol fermentation by more than a factor of 10.

optic-based sensing devices for detection of bacterial metabolism associated with degradation of wastes and monoclonal antibodies immobilized on optical fibers to provide remote sensing of hazardous chemicals in groundwaters and subsurface soil samples. Microbial consortia are being isolated for interaction with chemicals resistant to metabolism by a single organism, and investigations of both in situ and bioreactor containment degradation are ongoing.

Enhanced production of biomass feedstocks is also an important research area. Biotechnology has recently been applied to increase species productivity. This has included the use of tissue culture techniques to clonally propagate superior genotypes; investigation of somaclonal variation and biolistic transformation as a means of obtaining herbicide tolerance, insect resistance, and drought hardiness; and use of restriction fragment length polymorphism techniques to map hybrid poplar nuclear genome.

A recently initiated effort in environmental biotechnology incorporates those components of fundamental research relating to the responses of environmental species with applied microbiology, engineering capabilities, and chemical detection and sensing to address environmental restoration and waste management issues. Collaborative efforts with other national laboratories and universities and cooperative efforts with private industries through CRADAs are major strategies employed in this program.

Ultimately, successful application requires acceptance of biotechnology by the public. Simulation models are being used to evaluate transport and survival of genetically engineered microorganisms in the environment; and the ethical, legal, and social implications of genome manipulation are growing concerns that are central to the human and environmental risk analyses being conducted.

Budget projections for the Biotechnology Initiative are found in Table 4.11. Funding is provided from a number of sources, including the Office of Energy Research, the Assistant Secretary for Conservation and Renewable Energy, and DOE and non-DOE offices and programs.

Table 4.11
Budget projections by fiscal year for the Biotechnology Initiative
($ in millions—BA)

	1993	1994	1995	1996	1997	1998
Operating expense	17.6	21.7	23.1	25.1	26.3	27.6
Capital equipment	0.5	0.8	0.8	1.0	1.0	1.2

Other Initiatives

The following additional initiatives are proposed under program discussions in Sect. 5, "Scientific and Technical Programs."

- Office of Energy Research
  - High-Energy Physics Research Program and the Oak Ridge Detector Center
  - Radioactive Beams/Recoil Mass Spectrometer/Gammasphere
  - Development of Melton Valley as a Strategic Resource for ORNL
  - Center for Excellence in Research Reactors
  - Retention of Pool Critical Assembly
  - Advanced Photonics for Environmental Needs
  - Biological Imaging and Analysis Center
  - Subsurface Research
  - ORNL Genome Program
  - Center for Global Environmental Studies
  - Education Technology

- Assistant Secretary for Nuclear Energy
  - Modular High-Temperature Gas-Cooled Reactor—Direct Cycle
  - Center for Excellence in Research Reactors (see Office of Energy Research)
  - Retention of Pool Critical Assembly (see Office of Energy Research)
  - Actinide Recycle
  - Nuclear Power for Space Applications

- Assistant Secretary for Conservation and Renewable Energy
  - Better Energy Technologies for the World

- Assistant Secretary for Environment, Safety, and Health
  - Center for Risk Management
  - Health Physics Instrumentation Center of Excellence

5 Scientific and Technical Programs

5 • Scientific and Technical Programs

U.S. Department of Energy

Office of Energy Research

The Office of Energy Research (DOE-ER) is the largest single sponsor of research at ORNL. It supports ORNL's major research programs in the basic physical sciences, fusion energy, and biomedical and environmental sciences (Table 5.1).

AT—Magnetic Fusion

The Fusion Energy Program at ORNL is a major component of DOE's Magnetic Fusion Program, the plans for which are outlined in the National Energy Strategy. Two characteristics distinguish ORNL in this activity: (1) the extensive collaboration both nationally (with numerous universities, industries, and national laboratories) and internationally (with ten countries) and (2) the breadth of the component subprograms in physics, technology, and systems studies. Work is carried out in several ORNL divisions; and major contributions are made by the Central Engineering, Computing and Telecommunications, and Oak Ridge Y-12 Plant organizations.

The goal of the Magnetic Fusion Program as stated in the National Energy Strategy is to prove that fusion energy is a technically and economically credible energy source by having an operating demonstration plant by 2025. This goal will require increasing emphasis on the nuclear aspect of fusion. ORNL is an essential participant in the program because of the multidisciplinary nature of ORNL's energy programs, the breadth of its fusion program, the capability for integration of fusion R&D areas, an excellent record in technology transfer to industry, and the potential of the Oak Ridge Reservation as a site for fusion nuclear technology R&D facilities, including major deuterium- and tritium-burning experiments. (See Sect. 4, "Summary of Major Initiatives.")

In support of the National Energy Strategy, the objective of ORNL is to have a leading role in

- the integration of confinement and technology issues needed for the understanding of fusion physics and for the improvement of the toroidal confinement concept,
- the solution of physics and technology issues for the high-duty factor/steady-state operation of a toroidal reactor,
- the attainment of adequate system reliability and maintainability,

Table 5.1
Office of Energy Research major program summary
($ in millions—BA)[a]

Budget and reporting code	Major program	FISCAL YEAR 1991	1992	1993	1994
AT	Magnetic Fusion	26.4	27.5	41.1	50.4
KA	High-Energy Physics	0.4	0.5	1.3	1.6
KB	Nuclear Physics	13.8	15.3	12.9	14.2
KC	Basic Energy Sciences	99.2	128.6	141.8	189.1
KD	Energy Research Analyses	0.6	1.1	1.5	1.5
KG	Multiprogram Energy Laboratory Facility Support	6.5	2.8	14.9	25.5
KP	Biological and Environmental Research	28.7	33.7	40.6	60.6
KS	Superconducting Super Collider	1.1	0.1	0.5	0.5
KT	University and Science Education	1.5	1.3	1.6	1.7
KU	Laboratory Technology Transfer	0	2.1	1.8	1.0
KV	University and Science Education, Defense–Related	0	0.3	0.4	0.4
	Landlord activities[b]	0.1	17.0	83.8	118.5
Total		**178.3**	**227.5**	**342.2**	**465.0**
Percentage of total Laboratory funding		32.8	37.5	38.6	44.1

[a]Includes operating BA, capital equipment, construction, and proposed construction as noted in Table 10.5 in the "Resource Projections" section.
[b]Includes general-purpose equipment and general plant project funding and several field-work proposals for the Occupational Safety and Health Administration (OSHA) and other safety activities.

- the development of radiation-resistant and low-activation materials,
- the development of a nuclear capable site for fusion technology R&D, and
- the broader exploitation of technologies and capabilities developed in the Fusion Energy Program and the transfer of these technologies to American industry.

Magnetic fusion sets many demanding technology goals for high-field superconducting magnets, heating and fueling systems, materials, lithium blankets to breed tritium, and remote-handling techniques. These components must withstand the fusion environment of 14-MeV neutrons.

The achievement of these goals is important for the world because fusion is essentially an unlimited source of energy that also has the potential for substantially reduced environmental impact compared with other energy sources. Support for the ORNL program comes from three subprograms: Applied Plasma Physics (AT05), Confinement Systems (AT10), and Development and Technology (AT15). The first subprogram funds theory, atomic physics, diagnostic development, and modest sized innovative experiments; the second, confinement experiments, the Tokamak Physics Experiment, and some applications of plasma technology; and the third, materials research, plasma technology, the ITER Project, and systems studies.

Theory • The ORNL fusion program uses theoretical and computational methods to formulate, validate, and apply models of plasma behavior in toroidal fusion plasma confinement systems. Successful models lead to improved operation of present systems and to design of better ones for the future. A primary emphasis here is on understanding plasma confinement and its limitations in tokamaks; similar emphasis is given to an alternative toroidal confinement concept—the stellarator/torsatron. Essential similarities of the internal magnetic fields and the plasmas in the two concepts simplify comparative analysis and yield progress in control of each of them. Differences between the systems are exploited to isolate specific physical phenomena and to provide means to control and improve effectiveness of the experiments. The most important differences between tokamaks and stellarators are instabilities driven by currents parallel to the magnetic field and the essentially pulsed nature of the tokamak confining fields, both of which are absent in stellarators.

ORNL contributions include work in the following areas:

- Development of instability simulation models and computational approaches and application to specific experiments so that the models can be validated and improved.
- Analysis of anomalous transport of particles and energy as driven by instabilities and modified by nonplasma effects such as ionization/recombination processes at the periphery. Instability-driven turbulent processes are assessed using ORNL-developed and other instability simulation models.
- Definition of the relations between plasma flows, rotation, and collisional processes modified by the primary magnetic and electric fields. These are critically influenced by effects from turbulence phenomena. Because the instabilities and turbulence are influenced in turn by them, self-consistent theories are essential to unravel interconnections of all these phenomena.
- Establishment of means by which externally imposed magnetic and electric fields can be used to tailor particle drift behavior. This allows experiments to have reduced orbit losses and lowers the underlying collisional transport.
- Defining and developing fueling and heating techniques to adjust profiles, control energy and particle sources, and modify loss factors. Energy and particle sources permit tailoring profiles of plasma density, pressure, and current, which are controlling factors in overall confinement performance and define stable/unstable behavior.
- Developing direct drive of plasma current by radio frequency (rf) and neutral beams offers means to extend the pulse length in tokamaks and may eventually allow extension to true steady-state operation. Our work includes efforts to improve the basic rf launch structures so that they are most effectively able to provide drive for plasma currents.

The theoretical effort is directed toward applications that improve the U.S. tokamak initiatives (the ITER effort, the U.S. New Initiatives effort, and the Advanced Reactor Innovation and Evaluation Study) and that enhance the U.S. and world programs in the stellarator field.

Atomic Physics • The development of data bases and theoretical models for atomic physics and fusion plasma diagnostics has been undertaken in the Physics Division. Within the past several years a powerful new source of multiply-charged ions has contributed 90% of the available ionization cross-sectional data base for fusion-relevant ions and should continue to support fruitful research for many years. In a separate program a very promising laser-based diagnostic for fusion alpha particles was installed on the Advanced Toroidal Facility (ATF) and has completed the proof-of-principle test.

Small Tokamak Program • A Small Tokamak Program was established in 1990 to explore the possibilities of using small and small-R_0/a tokamaks for testing technologies critical to fusion energy development. The program contains three major research activities:

- Development of low-aspect-ratio tokamak concepts. Ideas from ORNL have led to experimental tests of such devices at several sites and to collaborations—most notably at the Culham Laboratory in England, the Instituto De Pesquisas Espacias in Brazil, and the A. F. Ioffe Physico-Technical Institute in the Commonwealth of Independent States (CIS) (formerly the U.S.S.R.).

- Design of a small steady-state tokamak (TST) to test divertors. Such divertor solutions are needed by steady-state tokamaks such as ITER and the Tokamak Physics Experiment (see Fig. 5.1). A preliminary proposal to design and build such a TST is complete.

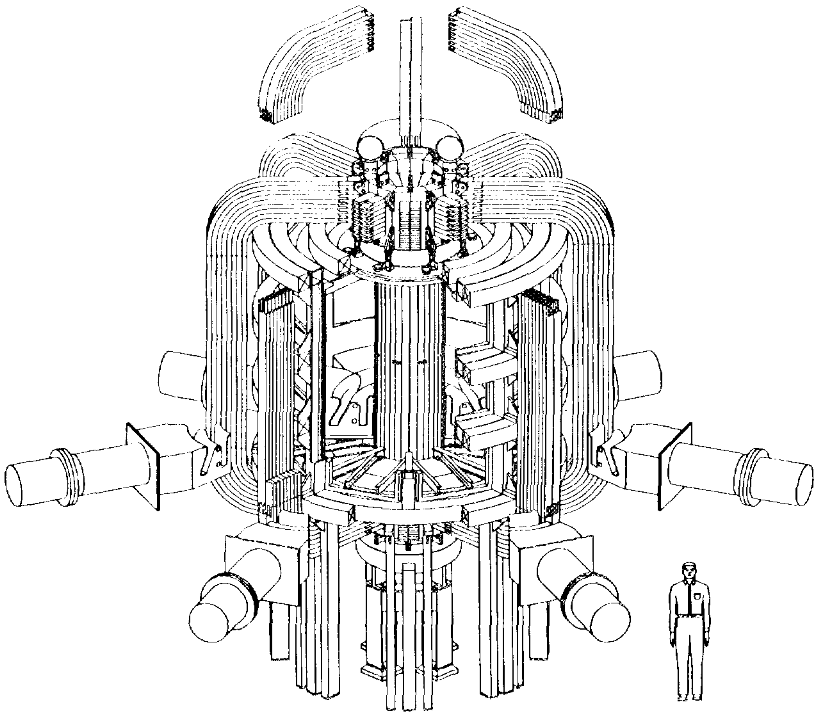


Figure 5.1
TST design configuration for a duty factor target of 10%, using a modular cassette divertor, large access ports, and eight demountable toroidal field coils

- Design of a small steady-state neutron tokamak (TSNT) to test fusion blankets. Success of the preceding efforts and the $Q \sim 1$ operation in the JET and the TFTR would provide the technical basis for a TSNT to produce a D-T neutron wall load of $W_L \sim 1$ MW/m^2. This would be adequate for testing fusion technologies including the blankets. A physics and engineering concept for a TSNT is being developed.

Advanced Toroidal Facility • The main focus of the Confinement Systems subprogram at ORNL has been the ATF experiment, the world's largest stellarator (a type of toroidal plasma confinement device). ATF has the flexibility to study various magnetic configurations and to make unique contributions to the understanding of toroidal confinement. The ATF program features collaborations with researchers from other institutions in the United States, Japan, Spain, Russia, Ukraine, and Germany. Key contributions to understanding have been made in a number of areas: access to the second region of stability, scaling of the plasma-driven (bootstrap) current, plasma-edge turbulence and associated transport, effects of magnetic field perturbations and electric fields, and global transport scaling. Recent experiments have focused on transport modulation experiments and fluctuation measurements to explore anomalous transport mechanisms underlying the global behavior of the energy confinement time. Figure 5.2 shows density fluctuation measurements obtained throughout the plasma volume and the mechanisms thought to be responsible. Microwave scattering measurements conducted in collaboration with the General Physics Institute (Moscow) suggest the presence of trapped-particle effects like those expected for the dissipative trapped-electron mode instability. The density fluctuation amplitude is larger on the small-major-radius side of the torus where the helically trapped particles are expected to be well confined. Plasma operation near the marginal stability condition for such instabilities could account for the persistence of flat and hollow density profiles in stellarator experiments.

ATF ceased operation in November 1992 to allow repair of damaged segments in one of the two helical windings. Pending DOE approval, ATF could restart at the end of 1993.

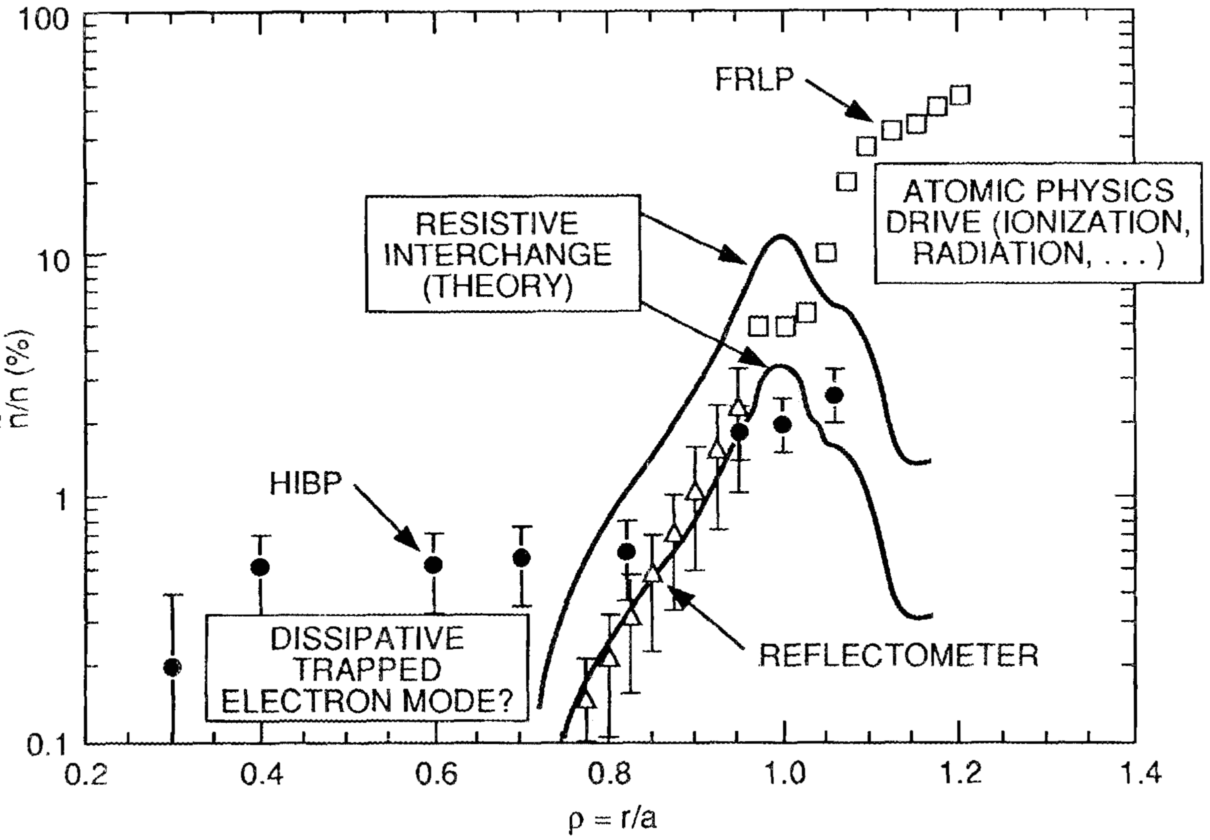
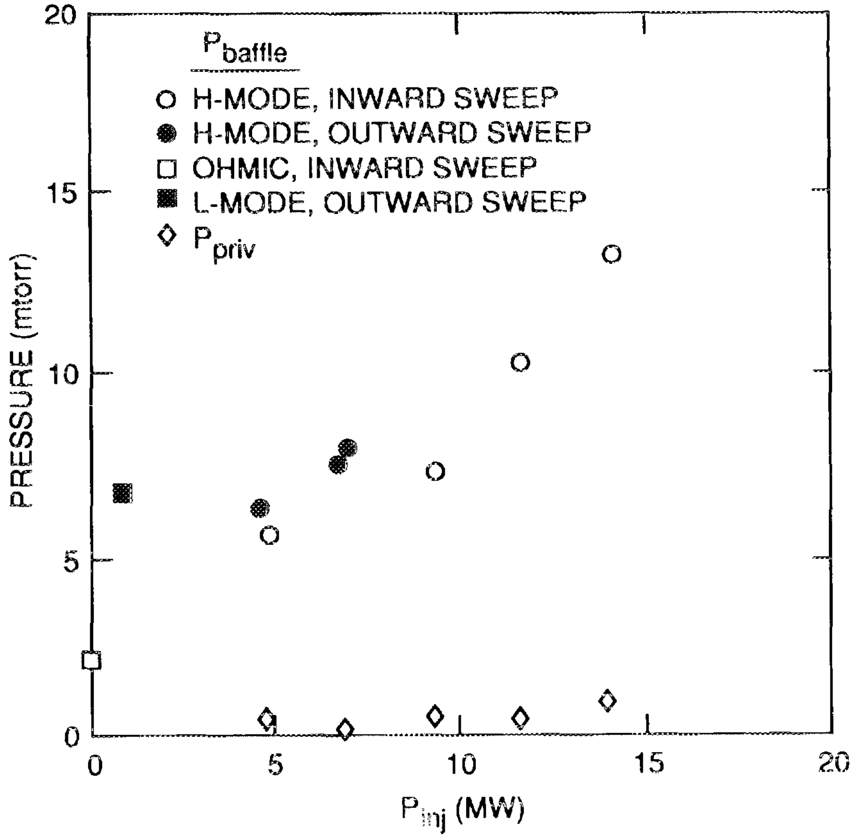


Figure 5.2 Radial profile of density fluctuation levels in ATF as measured by a heavy ion beam probe (HIBP), microwave reflectometer, and a fast reciprocating Langmuir probe (FRLP)

Collaborative Programs • With the hiatus in ATF operation there is an increased emphasis on collaborations with other institutions. These programs include work on transport studies, divertors, and fueling and heating on DIII-D at the General Atomics company and the Plasma-Burning Experiment (PBX-M) and the TFTR at the Princeton Plasma Physics Laboratory (PPPL). These new programs extend existing collaborations on the Tokamak Experiment for Technically Oriented Research (Germany), Tore Supra (France), and JET (European Economic Community); on techniques for understanding and controlling the plasma boundary; on pellet fueling; and on ion-cyclotron heating and current drive. One example, a result of the ORNL divertor collaboration on DIII-D, is shown in Fig. 5.3. The figure depicts the pressures under the divertor baffle region and in the private flux region as functions of the injected neutral beam heating power. The achieved pressures are very high, indicating efficient particle removal with the pumped divertor. A common feature of many of these programs is the application of successful ORNL technology developments, such as the ion-cyclotron range of frequency antennas and pellet injectors, onto major confinement devices as the basis of integrated programs involving theoretical, experimental, and developmental personnel. Two noteworthy examples are described below.

Fast Wave Current Drive Program • Experiments are currently under way on the DIII-D tokamak at General Atomics (San Diego, California) to demonstrate fast wave current drive under reactor-relevant conditions using a four-element antenna array designed and built by ORNL. Planning and implementation of the experiments is a collaborative effort between the Fusion Energy Division and General Atomics. Fast wave current drive involves driving an electron current in a tokamak plasma by launching a directional spectrum of rf waves, which subsequently deposit their energy in the tail of the electron energy distribution, by means of a phased array of antennas. If the present experiments bear out the theoretical analysis, fast wave current drive is expected to be the most economical means of sustaining the plasma current in a tokamak fusion reactor.

Figure 5.3
Pressure-scaling studies in the collaborative DIII-D Advanced Divertor Program



The array is designed for 2 MW of rf power, which should, under optimum conditions, result in about 250 kA of fast wave current drive, representing 25 to 50% of the total current in the tokamak. The efficiency of current drive depends on both antenna and plasma factors. Unless the antenna can launch the desired wave spectrum and maintain this spectrum stably against modest changes in the plasma, the efficiency will be unacceptable. For this project it was necessary to conduct extensive development to optimize the antenna spectrum and to develop the necessary algorithms for phasing and impedance matching the antenna elements, which are all fed from a single rf transmitter. The plasma current is maintained at a constant value, so any current driven by fast waves is seen as a reduction in the voltage in the circuit maintaining the plasma current. Preliminary results are consistent with the predictions.

The time history of several plasma parameters is shown in Fig. 5.4. The top graph shows the applied electron cyclotron heating power (used to boost the electron temperature in the plasma) and the fast wave current drive power. Major divisions on the horizontal axis are 100 ms apart. The bottom trace shows the central electron temperature as determined by Thomson scattering. The middle trace shows the loop voltage. The horizontal lines at the three time slices indicated by solid vertical lines denote the expected levels of loop voltage in the absence of any fast wave current drive. At the first time slice, no rf power is present, and the expected loop voltage exactly matches the measured value. In the other two time slices, the first during the electron cyclotron heating pulse and the second after the electron cyclotron heating power was turned off, the measured loop voltage is 100 mV lower than expected, indicating the presence of plasma current driven by the fast waves.

Tritium Pellet Injector for TFTR • The tritium pellet injector for the TFTR shown in Fig. 5.5 is being constructed at ORNL to provide a cryogenic tritium pellet fueling capability for the TFTR D-T phase scheduled to begin in July 1993 at PPPL. The existing TFTR deuterium pellet injector, which was built at ORNL and commissioned on TFTR in 1986, is

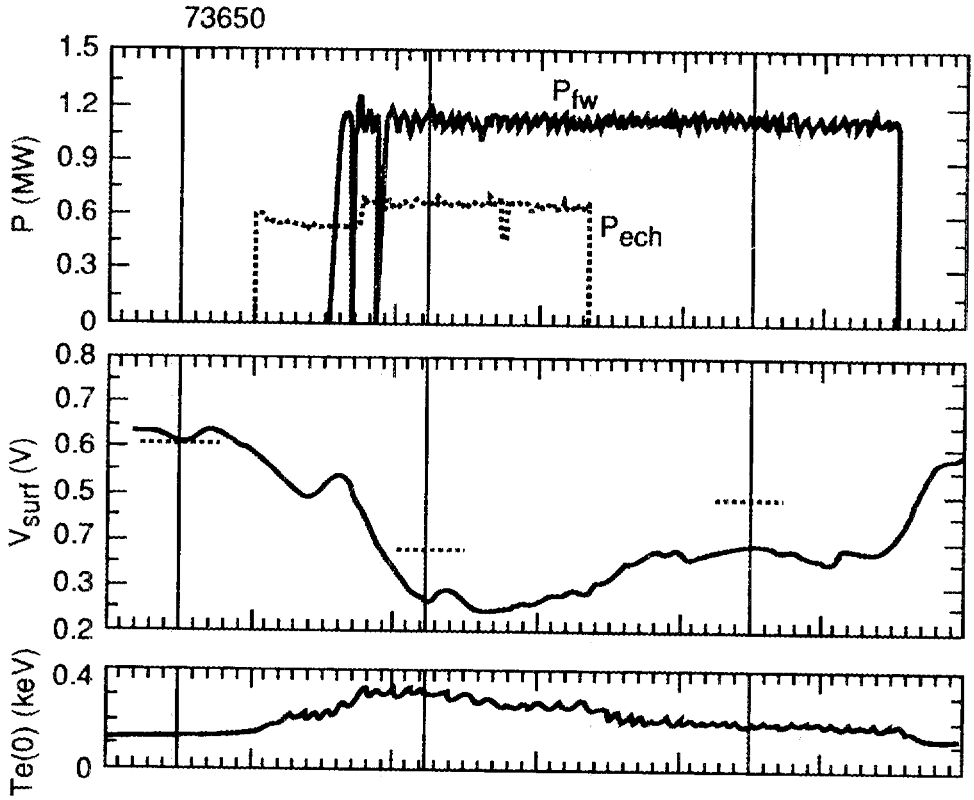
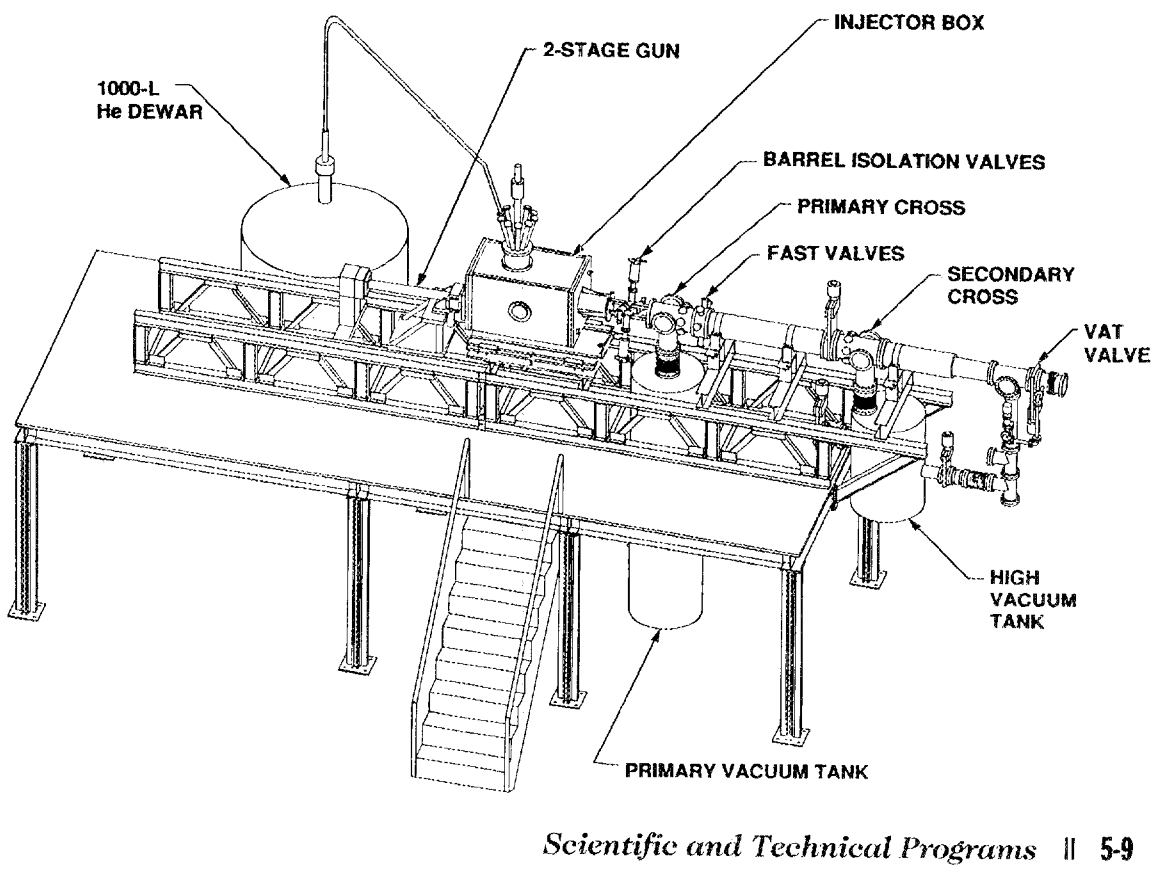


Figure 5.4
Loop voltage drops greater than expected for heating alone are observed during fast wave current drive experiments at π/2 phasing. (Figure from R. Prater et al., 1991 Annual Meeting of the American Physical Society Division of Plasma Physics, Tampa, Florida.)

Figure 5.5
Perspective view of the tritium pellet injector installation on TFTR



being modified to provide a four-shot, tritium-compatible, "pipe-gun" configuration with three upgraded single-stage pneumatic guns and a two-stage light gas gun driver. The pipe gun concept has been qualified by ORNL for tritium operation by the tritium proof-of-principle (TPOP) injector experiments conducted on the Tritium Systems Test Assembly (TSTA) at Los Alamos National Laboratory (LANL). In these experiments, tritium and D-T pellets were accelerated to speeds near 1.5 km/s. The tritium pellet injector is designed for pellet sizes in the range from 3.4 to 4.0 mm in diameter in arbitrarily programmable firing sequences at speeds up to about 1.5 km/s for the three single-stage drivers and 2.5 to 3 km/s for the two-stage driver. The injector was delivered to PPPL in March 1992. Use of the TPI on TFTR will permit access to both a regime suitable for initial alpha particle physics studies and a regime suitable for studies of particle and energy confinement in high-density D-T plasmas. The project is divided into two phases: Phase I activities allow the deuterium fueling capability to be used during 1992 operations, while the Phase II activities incorporate systems required for tritium operation and include an extended period of testing at the TFTR site, ending with the formation and acceleration of tritium pellets in 1993.

Materials Program • The Fusion Energy Materials Program has three major points of focus: (1) development of reactor structural materials, (2) development of first-wall and high-heat-flux materials, and (3) development of ceramics for electrical applications. Within the Office of Fusion Energy, these efforts are supported by the neutron interactive materials and the plasma interactive materials programs. The ORNL effort supports U.S. participation in the ITER as well as the ultimate objective of making fusion an economically competitive and environmentally attractive energy source.

In the structural materials program, the primary emphasis remains on qualification of austenitic stainless steels for ITER and the development of low-activation ferritic steels, vanadium alloys, structural ceramics, and ceramic composites (SiC/SiC).

Austenitic steels are the leading candidate for structural applications in ITER because of their advanced state of development and commercial practice. In a collaborative program with the Japan Atomic Energy Research Institute, we are investigating the effects of fusion reactor radiation damage levels on the engineering properties of these alloys. Central to this effort is the irradiation of these alloys in the HFIR with tailoring of the neutron spectrum to produce damage levels (transmutation-produced helium and displacements per atom) equivalent to those produced in a fusion reactor spectrum. These experiments are providing data and understanding of radiation response at temperatures and damage levels that are precisely those required for the ITER engineering design activities (i.e., 60 to 400°C, up to 30 displacements per atom).

Development of low- or reduced-activation materials is critical to achieving fusion's potential as a safe and environmentally attractive energy source. Development of low-activation ferritic steels requires that metallurgically important elements such as nickel, molybdenum, niobium, and nitrogen be removed or reduced to relatively low levels and that potential impurity elements be controlled to acceptable levels. To develop low-activation martensitic steels, tungsten is being used as a substitute for molybdenum, and niobium is replaced by tantalum and vanadium. The development activities are focused on the most critical or limiting property of this class of alloys—the radiation-induced shift in ductile-to-brittle transition temperature and reduction of fracture toughness. The vanadium alloys that are being considered for fusion have attractive activation characteristics, so compositional modification is not required to achieve this goal. The focus of our research on vanadium alloys is chemical compatibility with proposed fusion coolants and the effects of irradiation on fracture toughness. From the viewpoint of induced activation, SiC is the ultimate fusion structural material. Monolithic SiC is not considered because of its fracture properties. SiC/SiC composites offer an approach to improved fracture toughness. Our understanding of the performance of these materials in an irradiation environment is extremely limited. The focus of our present research is to explore the effects of irradiation on properties so as to provide a basis for accurately assessing the potential of SiC/SiC composites as fusion structural materials and to begin efforts to tailor these materials for the fusion environment.

The effects of irradiation on the dielectric properties of ceramic insulators are of critical importance in the successful design and operation of numerous systems in a fusion reactor (e.g., rf heating, plasma diagnostics). Our initial experimental work (initiated in

1991) has been directed at in-situ measurements of the loss tangent during ionizing and ionizing-plus-displacive irradiation. Results to date show an increase in loss tangent of nearly two orders of magnitude at a displacement rate of 1×10^{-7} displacements per atom per second. A change of this magnitude will impact materials selection and design of rf heating systems for ITER. Measurement of in-situ properties will be expanded to investigate radiation-enhanced dielectric breakdown and the effects of irradiation on structural evolution and mechanical properties.

Graphite and carbon-carbon research activities are part of the plasma interactive and high-heat-flux materials programs. Graphite and carbon-carbon composite materials are selected for these applications because their low Z number minimizes radiative heat losses for the plasma. However, their application requires graphite and carbon-carbon composites with extremely good thermal shock, erosion, and neutron damage resistance. Optimum thermal shock resistance is assumed to be offered by appropriately designed carbon-carbon composites (i.e., selected fibers, matrices, and architectures). Current work is directed toward the optimization of these materials for neutron-damage resistance.

Advanced Systems Program • The Advanced Systems Program has continued to focus on the definition and design of the next major tokamak project. Two conceptual design efforts, the Burning Plasma Experiment at Princeton (BPX) and the ITER have provided the basis for planning on both a national and an international scale.

After more than 4 years of preparation, the BPX project was cancelled early in FY 1992. ORNL had responsibility for five major systems and was involved in physics, engineering, and technology development. The DOE has appointed a national task force to define a new project to replace BPX at a much lower cost (~\$400 million). ORNL is participating in the national effort to define the mission and features of the new project, called the Tokamak Physics Experiment.

On the international scale, the cooperative effort by the European Community, Japan, the CIS, and the United States to design a fusion test reactor (ITER) will continue with the initiation in 1992 of 6-year engineering design activities. Between 1988 and 1990, ORNL was a major contributor to the conceptual design activities that defined the ITER concept. The Laboratory will contribute to ITER throughout the engineering design activities with contributions in physics and engineering design and R&D in fueling, rf heating, materials, and remote handling.

Several new programs in the advanced systems area have the potential for significant future involvement of ORNL, a Fusion Neutron Source Facility and a Fusion Pilot Plant Project. Plans by DOE and other countries indicate the need for a Fusion Neutron Source Facility. A recent study at ORNL considered an accelerator-based, beam target system for production of the fusion neutron spectrum. It was concluded that ORNL could provide important contributions to a national or international program to design, build, and operate a fusion neutron test facility. The Oak Ridge Reservation could provide an attractive site for a fusion neutron research facility. In FY 1992, ORNL is coordinating a national effort to develop a new concept that could lead to an international project to design, build, and operate such a facility.

The Pilot Plant Project has been proposed by Fusion Power Associates, ORNL, the Massachusetts Institute of Technology, and others as a demonstration of the production of high-grade heat in a fusion power plant configuration at the lowest possible capital cost. The advanced systems program staff have provided engineering design and systems analysis support to help define a small tokamak device to accomplish these objectives. Site studies indicate that the Poplar Creek Peninsula located near the K-25 Site would be an ideal location for both the Neutron Source and the pilot plant projects. Preliminary design studies will continue into FY 1993.

KA—High-Energy Physics

The High-Energy Physics Program is anticipated to grow in the future as a result of activity related to the national SSC Program. In addition to existing activity in radiation-shielding design, a significant increase in effort associated with the joint experimental High-Energy Physics Program among ORNL, UT, and other Southern Association of High-Energy Physics (SAHEP) universities (in particular, Duke, the University of Virginia, and the

University of Mississippi) is expected. The current high-energy physics R&D activities will continue to grow as the result of the strengthening of the in-house High-Energy Physics Group and of the collaborative research initiated through the recently established Oak Ridge Detector Center (ORDC). (See "Continuing Initiative—High-Energy Physics Research Program and the Oak Ridge Detector Center.")

Continuing Initiative

High-Energy Physics Research Program and the Oak Ridge Detector Center

Successful use of the SSC for high-energy physics investigations will require design and construction of a new generation of detector systems in parallel with the design and construction of the SSC. Preliminary R&D has been initiated for this purpose through both DOE and the SSC Project. The two large detector systems will be major development tasks that will cost several hundred million dollars. The task of building these detectors will not only involve targeting particular areas of high-energy physics and planning an associated research program, but it will also require a broad multidisciplinary approach to solve the various materials, engineering, data acquisition and analysis, and physics problems associated with the detectors. Close coordination among the ORNL science programs and Energy Systems' central engineering organization will be required.

The collaborations that started several years ago between southern universities and ORNL have continued and are guided by SAHEP. SAHEP is chartered under ORAU and has a membership exceeding 15 universities and other organizations, including ORNL. In addition, close ties are maintained with SURA. The creation of SAHEP was driven in part by the SSC Project and by a true desire to increase the high-energy physics base in the Southeast. The SAHEP organization acknowledged the strategic location and facilities of ORNL and recognized the importance of having ORNL play one of the focusing roles in the region. At present, several close collaborations have been established between ORNL and SAHEP members. These projects are detailed in this subsection as our involvement with the detector collaborations are discussed.

ORNL has a strong involvement with the Solenoidal Detector Collaboration (SDC) and the Gamma, Electron, and Muon (GEM) Collaboration. These groups are expected to produce the two large general purpose detectors that will be ready to investigate the "new physics at 40 TeV and 10^{-19} m" when the accelerator is operational in the late 1990s. The prime responsibilities that ORNL has assumed for the SDC collaboration include the design, engineering, and construction of the outer and intermediate central tracking chambers as well as the system integration of the entire central tracker, including inner, outer, and intermediate. The SAHEP members that are closely associated with this research include Duke University and Florida State University. In the GEM collaboration, ORNL plays a leadership role in calorimetry. Although the final choice of calorimetry technology has not been made, ORNL is in a favorable position to contribute in a major way to the design, engineering, and construction of the GEM calorimeters regardless of which technology option is chosen. The SAHEP members associated with GEM include the University of Mississippi and UT. In addition to the large SDC and GEM, ORNL is strongly coupled to the Super Fixed Target (SFT) B Physics Facility for the SSC that is headed by the University of Virginia, another SAHEP member. The SFT needs support in the area of fast radiation-hardened electronics and in the development and design of electronic chips.

To coordinate all of our SSC-related activities, the Oak Ridge Detector Center (ORDC) was formed almost 3 years ago. The purpose of the ORDC is twofold: to serve as the focal point for all science and engineering divisions involved in SSC-related research and to provide an organization interface with outside collaborators in the area of SSC detector R&D. The goals of the center are (1) to establish the Southeast as a major force in high-energy physics; (2) to enhance cooperation for joint detector R&D among ORNL, universities, and private industries; (3) to build a technology base for the engineering, designing, constructing, and testing of major components of SSC-style detectors (Fig. 5.6); and (4) to conduct detector R&D for other physics programs such as the Relativistic Heavy Ion Collider and the ANS. The research areas currently monitored by ORDC include detector simulation; radiation damage; and electrical, mechanical, and materials engineering. The funding for these research projects is currently coming either directly or indirectly

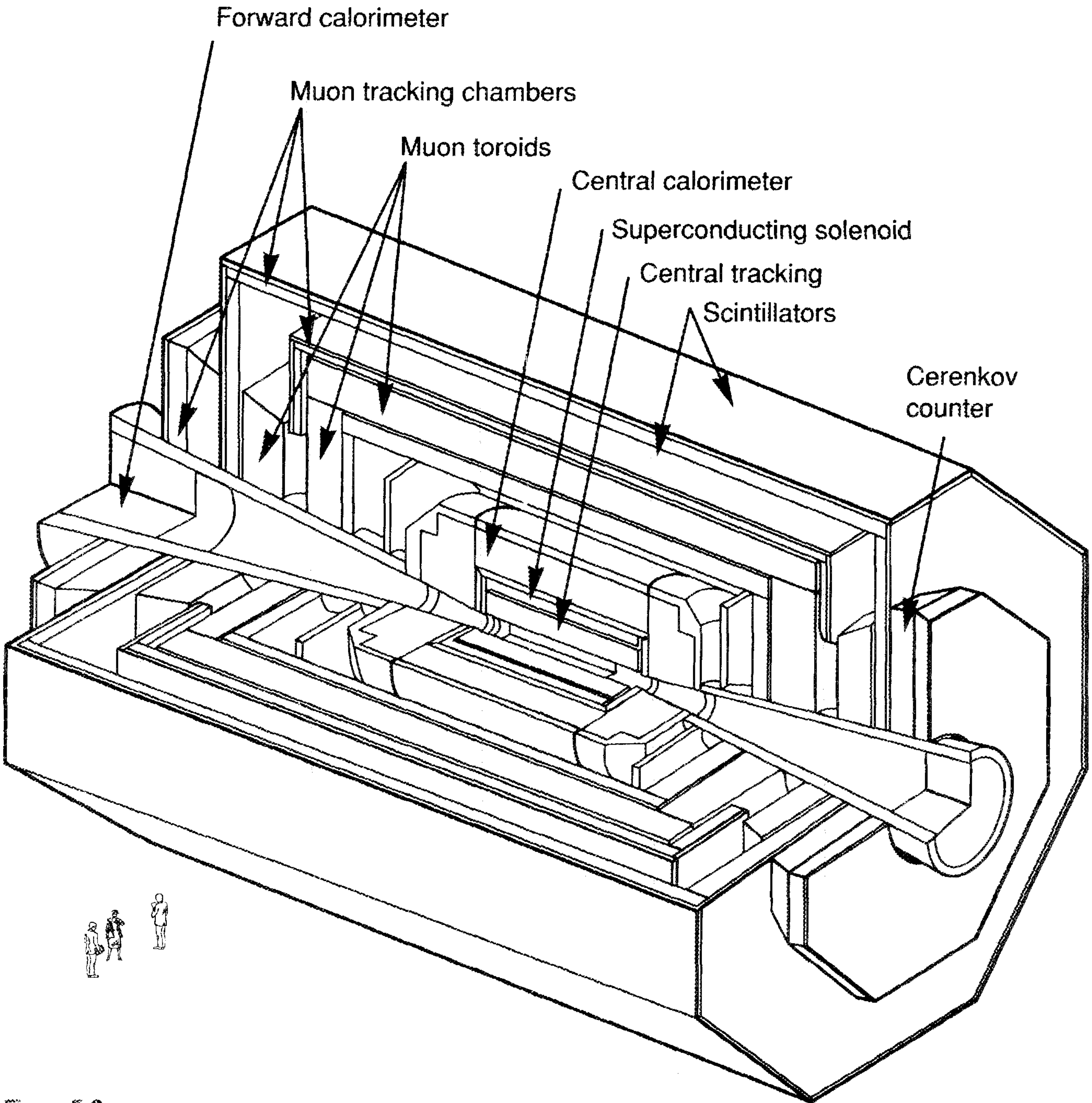


Figure 5.6
ORNL will be involved in designing, engineering, and building detector components for the Superconducting Super Collider. This figure shows the current design of a Solenoidal Detection Collaboration detector.

from the DOE SSC Laboratory and is anticipated to increase.

Because of our close connection with several of the SAHEP universities (i.e., Duke University, the University of Mississippi, UTK, and the University of Virginia), a pilot program of joint appointments is being sought. These appointments will be similar to the current joint appointments now existing between UTK and ORNL. In addition to providing a technical interface with the national and international high-energy community, these appointments will provide additional expertise in matching detector R&D to experimental requirements and in providing a continuing involvement of the Laboratory in the data-taking and data-analysis phase of the SSC Program.

The nature and extent of our involvement in the SSC are still evolving as the SSC Program gains momentum nationally. ORNL will continue to explore and to define the appropriate role of the Laboratory in this important national initiative. Because of ORNL's diverse multidisciplinary research program, the Laboratory is well positioned to make major contributions to numerous aspects of the SSC Program. The magnitude of the anticipated growth is indicated by the projected new funding (Table 5.2).

Table 5.2

Budget projections by fiscal year for the High-Energy Physics Research Program and the Oak Ridge Detector Center[a]

($ in millions—BA)

	1993	1994	1995	1996	1997	1998
Operating expense	2.5	3.5	3.5	3.5	3.5	3.5
Capital equipment	2.5	3.5	3.5	3.5	3.5	3.5

[a]Funds are being sought from the Office of Energy Research under Program KA, High-Energy Physics.

KB—Nuclear Physics

The Nuclear Physics Program emphasizes basic nuclear physics research, both experimental and theoretical, and operation of two user facilities: HHIRF and the Oak Ridge Electron Linear Accelerator (ORELA). Research is carried out at these two facilities by both in-house staff and visiting scientists from around the world. Experiments carried out at the HHIRF and ORELA include measurements with particle beams ranging in mass from neutrons to uranium ions and in energy from kiloelectron volts to gigaelectron volts.

KB02—Heavy-Ion Physics Task • Fiscal years 1992 through 1994 will be exciting and challenging for theHHIRF as it undertakes a modification that will enable it to provide radioactive ion beams (RIBs). (See "Continuing Initiative—Radioactive Beams/Recoil Mass Spectrometer/Gammasphere.") The importance of this type of initiative was recently acknowledged in the long-range plan of the Nuclear Science Advisory Committee where it was stated that "a facility producing beams of radioactive ions . . . is of high scientific interest and technically feasible. It would allow the study of nuclear structure and astrophysical reactions very far from the line stable nuclei and could provide new possibilities of reaching long sought island of stability of super heavy nuclei."[1]

The transition to an RIB facility will began toward the end of FY 1992 with the termination of operation of the Holifield as a national user facility. This concludes a remarkably successful decade in which the Holifield accelerator has provided 38,000 hours of ion beams for research to a large segment of the physics community. The following statistics illustrate the size of the operation. During the peak 3 years of 1987, 1988, and 1989, 316 researchers carried out research programs at the Holifield Facility. They represented 87 institutions from 24 states and 18 countries. The users included 127 students, 88 of which were candidates for the Ph.D. degree. In FY 1991 the Holifield had 127 outside users.

During the 2 1/2 years beginning July 1992, the Holifield accelerator system will be modified to produce RIBs with funds of $2.8 million being provided by DOE. This cost is modest and the time for implementation is short because the required two accelerators are already in place. (No other U.S. facility has such a fortunate juxtaposition). Light-ion beams from the Oak Ridge Isosynchronous Cyclotron (ORIC) will be used to bombard a thick target to produce nuclear reactions leading to radioactive products that will be ionized, mass separated, and then accelerated by a 25-MeV tandem. Ions with atomic mass up to 80 will be produced with energies sufficient to undertake programs in nuclear structure and astrophysics. The transition to an RIB facility will be completed at the beginning of FY 1995, and operation as a national user facility will be resumed.

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[1]*Nuclei, Nucleons, and Quarks: Nuclear Science in the 1990's, A Long Range Plan by the DOE/NSF Nuclear Science Advisory Committee*, U.S. Dept. of Energy and the National Science Foundation, December 1989.

To capitalize fully on the potential provided by RIBs, several other tasks are being undertaken in parallel to the RIB project. Chief among these will be the procurement and commissioning of the Recoil Mass Spectrometer (RMS). A new target room will be constructed to house the RMS as well as a large array of germanium gamma-ray detectors, known as the Gammasphere, now under construction at Lawrence Berkeley Laboratory (LBL). The RMS, with a projected cost of $2.2 million, is jointly funded by DOE, ORNL, ORAU, INEL, Vanderbilt University, the state of Tennessee, UT, and several other universities. This device has unmatched capabilities for observing very weakly produced isotopic species and thus is an excellent tool for observing the RIB-induced reaction channels leading to proton-rich nuclei extremely far from the valley of beta stability.

The low- and medium-energy research program includes a broad range of studies using heavy ion beams from accelerator facilities around the world. Research is carried out in three broad categories—nuclear structure, nuclear reaction spectroscopy, and nuclear collision dynamics; these areas overlap considerably. Research in nuclear structure is concerned primarily with the structure of nuclei at high spin and involves study of high-spin-state spectroscopy, nuclear lifetimes, chaotic behavior in rapidly rotating nuclei, and nuclei far from stability. These areas of study will be greatly enhanced by the development of accelerated radioactive beams at ORNL. Giant resonances in both "cold" and "hot" nuclei are the primary area of study in the reaction spectroscopy field. Areas of study include nonstatistical effects in the giant dipole resonance (GDR) in the same compound nucleus formed via different reactions, loss of GDR strength with increasing nuclear temperature, and nuclear temperature effects in the GDR width. Nuclear-collision-dynamics research studies the details of the interaction between nuclei when they collide at energies from below the Coulomb barrier to several hundred million electron volts. These studies involve measurements on such topics as subbarrier fusion, projectile fragmentation, and orbiting reactions.

Each of these three areas of research is carried out primarily by using major research equipment developed by the research staff. Nuclear structure research uses close-packed arrays of Compton-suppressed germanium detectors. Reaction spectroscopy studies utilize a newly commissioned large array of BaF_2 scintillation detectors that are designed for use with photons of energy up to 300 MeV. This array, the largest of its type in the United States, has been used in 23 experiments since it became operational in 1990. Much of the study of reaction dynamics is carried out using a multielement heavy-ion, light-ion detector system that can detect coincident reaction products over a very wide range of mass and energy.

At higher energies heavy ion reactions are studied with ultrarelativistic projectiles of 200 GeV per nucleon at the Super Proton Synchrotron located at the CERN European Laboratory for Particle Physics, Geneva, Switzerland. The primary purpose is to study the production and characteristics of the quark-gluon plasma that may be formed in reactions between nuclei at these energies. ORNL plays a major role in the CERN-based WA80 collaboration as well as in the succeeding experiment, WA93. In both experiments emphasis is placed on photon measurements. Because of their noninteracting properties, photons constitute one of the best probes of early reaction phases. ORNL has built the calorimeters of WA80 and continues to operate them. Plans call for a major ORNL contribution to the photon-detection capabilities of WA93 in the form of readout electronics.

If quark-gluon plasma is formed at the near-threshold energies of the Conseil Européen pour Recherche Nucléaire (CERN) Super Proton Synchrotron, it will be a baryon-rich plasma. Energies available at the Relativistic Heavy Ion Collider (RHIC) under construction at Brookhaven National Laboratory, however, are expected to lead to a relatively baryon-free plasma dominated by created particles. ORNL has a leadership role on one of the two major detectors, the Photon Electron New Heavy Ion Experiment (PHENIX), under consideration for the RHIC. This detector emphasizes measurements of electrons, muons, and photons. Because of their penetration properties, the leptons are considered to be excellent probes of the quark-gluon plasma. A certain fraction of muon and electron pairs results from the decay of vector mesons, the properties of which are likely to be a good signal of creation of dense matter and of deconfinement. ORNL is in charge of a major R&D activity, the BNL-based RD-10 experiment, in support of the measurement capability of PHENIX. A technical proposal is being prepared for PHENIX.

Continuing Initiative

Radioactive Beams/Recoil Mass Spectrometer/Gammasphere

A continuing initiative for the HHIRF is the development of the capability for producing and accelerating radioactive ion beams. This initiative seizes on a new scientific opportunity for the HHIRF and accommodates to changes in the plans for Gammasphere. Overall it builds on the previous initiative for Gammasphere and the long-range plan to provide a world-class center for nuclear structure physics and nuclear astrophysics at the HHIRF (Fig. 5.7).

Two events have altered significantly the Gammasphere initiative: first, the threatened loss of DOE funding for operation of the HHIRF, and second, the DOE decision that Gammasphere will be moved between laboratories. A consequence of the latter is that the presence of Gammasphere will not ensure the longevity of any facility. Because of this, and because of the existing uncertainty about the future of the HHIRF, an agreement was reached that the assembly and initial operation of Gammasphere will be at LBL. After 18 months of operation, a mandated move of Gammasphere will occur. During this same period, the development of a radioactive ion beam capability at the HHIRF will be supported. This is a significant new initiative in the nuclear physics community and one on which ORNL is well positioned to capitalize. The president's budget for FY 1993 contains funding for this project. The importance of this is that radioactive beams would give the HHIRF a truly unique capability (worldwide) and would constitute a strong rationale for longevity of the facility.

At the HHIRF the combination of the existing ORIC and a 25-MV tandem accelerator provides the opportunity for producing a large variety of low-energy, proton-rich, radioactive heavy-ion beams at modest cost. An intense light-ion beam from ORIC will produce radioactive isotopes (via fusion reactions in thick targets) that would then be prepared for reacceleration in the tandem accelerator. Because both accelerators exist at the HHIRF, as does an appropriately shielded target room for the Isotope Separator on Line source, the HHIRF offers a quick,

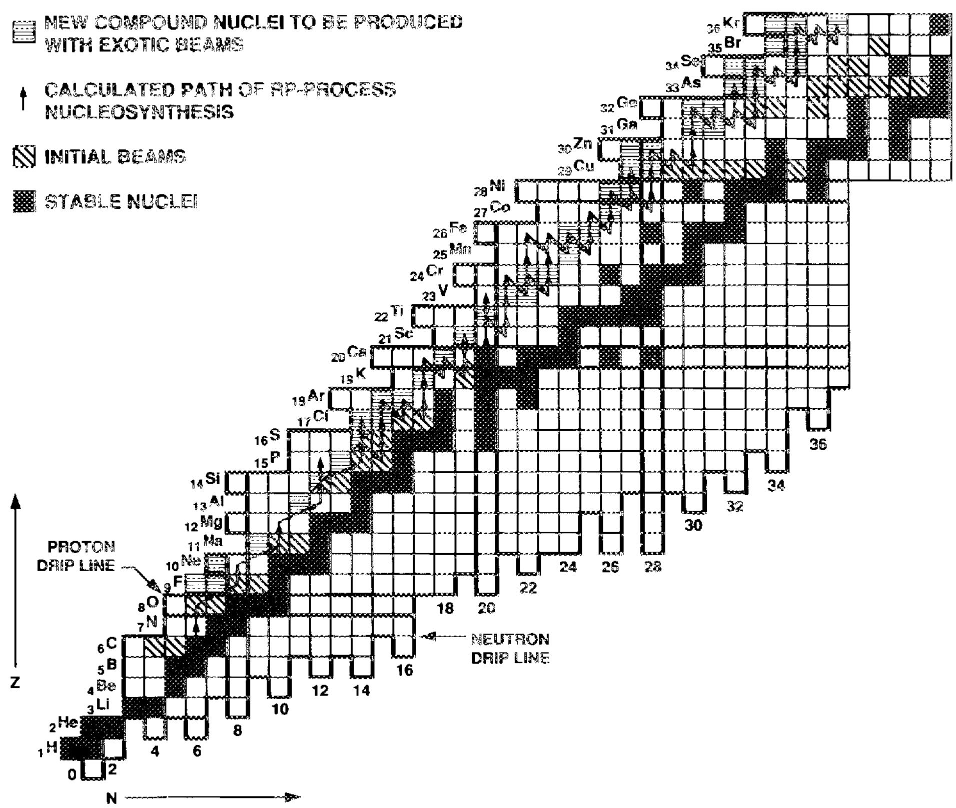


Figure 5.7 Expanded studies made available by the Radioactive Ion Beam Facility

cost-efficient method for producing radioactive beams. The use of the HHIRF tandem accelerator (designed to accept low-energy, negatively charged heavy ions) as the postaccelerator of such a facility allows heavy-ion beams up to mass 80 to be provided. More than 200 new proton-rich compound systems can be produced using stable targets and the beams initially expected from the facility. Many of these are of special interest for studies in nuclear physics and astrophysics.

The Gammasphere initiative is thus deferred. The first priority is to ensure that the HHIRF is successful in the development of a radioactive ion beam capability. The acquisition of the new RMS (intended to complement Gammasphere) will continue, and it will become a crucial experimental device to exploit the radioactive beam capability. We feel confident that the radioactive beam capability, along with the presence of the RMS, will make the HHIRF a very attractive site for Gammasphere at the time of the first move. Table 5.3 presents budget projections.

Table 5.3

Budget projections by fiscal year for development of radioactive ion beam capability at the Holifield Heavy Ion Research Facility[a]

($ in millions—BA)

	1992	1993	1994	1995	1996	1997	1998
Operating expense	3.3	3.0	3.3	4.0	4.0	4.0	4.0
Capital equipment	0.5	0.2	0.2	0.3	0.4	0.4	0.5
AIP[b] funds	0.6	0.8	1.0	0	0	0	0

[a]Funds are being sought from the Office of Energy Research under Program KB, Nuclear Physics.
[b]Accelerator Improvement Project.

KB03—Nuclear Theory Program • The Nuclear Theory Program centers on studies of nuclear reactions and structure at low and high energies. Major parts of this research are as follows: (1) pair production from relativistic heavy-ion collisions, (2) string and parton models of ultrarelativistic heavy-ion collisions and hadronization, (3) quark models of mesonic structure, (4) models of low-energy direct reactions and collective motion, (5) relativistic models of nuclear structure, and (6) mean-field models of low-energy nuclear reactions and structure.

In collaboration with UT and Vanderbilt University, the Center for Computationally Intensive Physics has been established in the Physics Division to carry out interdisciplinary research in nuclear, particle, and atomic physics. The activities of the center focus on those aspects of the program that can greatly benefit from the application of high-performance computing. A Cooperative Scientist appointment (jointly with UT) has been made to support the activities of this center, and efforts are under way to seek new funding.

KB04—Low-Energy Nuclear Physics Program • The Low-Energy Nuclear Physics Program supports several tasks, including operation and research at the ORELA, a unique pulsed-neutron-source accelerator facility for measurements by time-of-flight spectrometry of neutron cross sections and related quantities over the entire range of 0.001 eV to about 80 MeV. Funding is also provided for related activities including the evaluation of neutron cross sections for the national Evaluated Nuclear Data Base as well as nuclear model development.

This program provides results important to basic physics as well as the bulk of the nuclear data used for applied purposes in the United States. Current basic physics work has provided the first nonzero value for the polarizability of the neutron, unique data on high-temperature superconductors around their critical temperatures, and work is under way to study the neutron-electron interaction. Measurements of neutron transmission, differential elastic scattering, total inelastic, capture, fission, and neutron and gamma-ray emission cross sections are done to meet needs of engineers and scientists who need nuclear information in their work.

This program also supports a vigorous effort to study the details of giant multipole resonance excitation and decay. These studies make use of accelerator facilities at the Grand Accélérateur National d'Ions Lourds in France, the Indiana University Cyclotron, and the Texas A&M University superconducting cyclotron. Recent efforts have involved studies of isovector giant resonances through Coulomb excitation using medium-energy heavy ions and photon decay of the resonances. Of particular interest is the use of such techniques to search for the excitation of multiphoton giant resonances.

KC—Basic Energy Sciences

The Basic Energy Sciences (BES) Program supports a broad spectrum of research in the physical sciences. The two largest subprograms are Materials Sciences (KC02) and Chemical Sciences (KC03). Presidential initiatives central to this program are the now-formed Advanced Materials and Processing Program (in KC02) and the upcoming initiative in Advanced Manufacturing (in KC04). Several key issues facing these subprograms include a decision on shutdown or restart of the Bulk Shielding Reactor, development of the ANS (see "Summary of Major Initiatives"), revival of the HFIR-based neutron-scattering and irradiation programs, increased efficiency and effectiveness in user interactions, and technology transfer.

KC02—Materials Sciences • The Materials Sciences Program supports fundamental materials R&D including neutron scattering; synthesis and characterization of new materials; high-temperature materials; ceramic processing; superconductivity; ion-beam, laser, and plasma processing; and theoretical studies for advanced energy-related materials. The Materials Sciences Program also supports a number of user facilities including the Surface Modification and Characterization/Collaborative Research Center (SMAC/CRC), the Shared Research Equipment (SHaRE) Program, the National Center for Small-Angle Scattering Research, and the Neutron Scattering Facility at the HFIR. These facilities had 243 guest users in FY 1991. Two of the Laboratory's initiatives are in the materials sciences: the ANS and the MS&E Complex. KC02 funding is expected to increase sharply during the conceptual design phase of the ANS, although the core program is expected to experience no growth during this period.

KC02 01—The BES Metallurgy and Ceramics Program • This program provides the scientific foundation and fundamental framework required for the development of advanced materials and innovative processes. The tasks include synthesis, processing, fabrication, characterization, and the development of models and mechanistic understanding. Research in synthesis and processing science includes the development of fabrication and joining techniques for advanced intermetallic alloys, ceramics, and composite structures. Important to all of the tasks is the application and development of advanced characterization techniques including analytical electron microscopy, X-ray diffraction, atom probe field ion microscopy, mechanical properties microprobe, and ion beam techniques. A strong first-principles theory effort underpins all aspects of the program. Interactions with scientists from industry, universities, and other national facilities are important to the research. The SHaRE Program and the Oak Ridge Synchrotron Organization for Advanced Research (ORSOAR) Program are supported through both ORAU and ORNL. The SHaRE Program provides access to our advanced analytical microscopes, the Van de Graaff accelerator facility, and the nanoindenter. The ORSOAR Program supports an X-ray station at the National Synchrotron Light Source.

Programmatically, there will be continued emphasis on synthesis and processing as part of the BES Center of Excellence in Synthesis and Processing. The proposed ORNL Advanced Materials and Processing Program will expand research on densification of ceramics and intermetallics, welding science, and atomic size effects in alloy fabrication. Additional support for the Radiation Effects Task allowed enhancement of neutron irradiation research. Efforts to revitalize our neutron radiation effects studies will continue. In other areas, the development and construction of both the Multielement Imaging Atom Probe and the High Temperature Mechanical Properties Microprobe are scheduled for completion during FY 1992. The atom probe will allow three-dimensional mapping of the position and elemental identification of the atomic constituents of conducting materials. A new joint initiative is proposed by staff in the Metals and Ceramics and Solid State divisions for application of the mechanical properties microprobe to extremely hard, thin films of boron nitrides and oxides grown with electron-cyclotron resonance plasma processing techniques.

The ongoing assessment of the program, a result of continuing flat budgets and escalating costs, has led to the dissolution of the Structure and Properties of Surfaces and Interfaces Task. The nanoindentation research has been merged with the Microcopy and Microanalysis Task. Investigations of the effects of ion implantation on ceramics will be continued, at a reduced level, in the Radiation Effects Task. These changes will consolidate related research tasks and strengthen the remaining program.

Future program initiatives include investigation of the role of stresses, transformations, and fracture in weldments; the CAMA; establishment of a first-principles theory effort in ceramics; the X-ray microprobe; and enhancement of postdoctoral, guest scientist, and graduate student appointments to equal the number of full-time-equivalent (FTE) research staff supported by the program. The CAMA is an integral requirement for the successful application of many advanced characterization techniques. Included in this proposal are both the upgrade of instrumentation and a building designed for the specific requirements of modern analytical equipment. The X-ray microprobe would be sited at the Advanced Photon Source at ANL. It would allow unprecedentedly low levels of detection for structural and chemical characterization and identification.

KC02 02—The Solid State Physics Program • The Solid State Physics Program spans basic and applied research. Existing expertise will be directed to continuing and new basic research for the Advanced Materials and Processing Program. Applied research is under way in a CRADA with Eveready Battery Company on "Development of a Lithium Microbattery Packaging Technology," and two others are in the approval process. Unique facilities at ORNL are utilized to investigate a variety of research problems in condensed matter physics and materials science. The intense neutron beams available at HFIR are used for studies in the Interatomic Interactions in Condensed Systems and Structure and Dynamics of Energy-Related Materials Programs. The Small-Angle X-Ray Scattering Program supports these activities. Materials prepared by a number of researchers, both at ORNL and elsewhere, are investigated at these user facilities. The extensive ion beam facilities of SMAC/CRC are used to characterize and alter the near-surface region of a wide variety of materials. The Ion Beam Analysis and Ion Implantation Program utilizes these facilities, as do collaborators from several ORNL divisions and numerous universities and industries.

The Semiconductor Physics and Photovoltaic Materials Program is concerned with the processing and investigation of multilayer semiconductor and superconductor films and with the preparation of high-efficiency solar cells. The Properties of Advanced Ceramics Program studies single-phase and composite electrolyte and electronic ceramic materials in thin-film and bulk forms. The Synthesis and Properties of Novel Materials Program prepares and characterizes a variety of research specimens for study within the Solid State Division and throughout the KC02 Program. The Surface Physics Program investigates the atomistic structure of surfaces of metals and alloys and measures their electronic and vibronic properties. The Structural Properties of Materials—X-Ray Diffraction and the Electron Microscopy of Materials Programs—use a variety of sophisticated techniques to characterize materials associated with all the solid state physics programs. Superconductivity research is centered in the Physical Properties of Superconductors and the Superconductors with High Critical Temperatures Programs, but much research on this subject is performed in many groups in several divisions at ORNL. The principal task of the Theory of Condensed Matter Program is to ensure a firm theoretical basis for the experimental programs.

In 1991, high-power (85-MW) operation of the HFIR was resumed, and reactor availability has steadily improved over the past year. The neutron-scattering user program is recovering rapidly and is approaching historical levels from prior to the shutdown. Instrument upgrades achieved during the shutdown and new initiatives in colloidal systems and neutron reflectometry are contributing to an increased vitality of the Neutron Scattering Program. The proposed guide hall and new instrumentation are essential to this program and to preparations for ANS. Significant progress continues to be achieved in the theory and application of Z-contrast electron microscopy, and a new 300-kV scanning transmission electron microscope (STEM) is scheduled for delivery in CY 1992. This instrument will be the highest resolution electron microscope in the world. Progress in high-temperature superconductivity continues to be outstanding with a coordinated effort of about ten research groups and new results in synthesis and processing, critical current behavior, superconducting superlattices, and theory. New initiatives in the Synthesis and Properties of Novel Ceramic Nanocomposite Macromolecular Thin Films and Structures of Anisotropic Colloidal Materials programs are under way.

A new 2% initiative on atomistic mechanisms in interface science has been approved for FY 1994. This program is intended to develop a new approach to interface science with far-reaching scientific and technological implications for advanced electronic, superconducting, ceramic, and intermetallic materials. Based on the unique capability of Z-contrast electron microscopy to reveal the atomic scale structure and chemistry of interfaces, the program seeks to close the synthesis, characterization, and modeling loop for a broad class of interface-controlled materials. This program will benefit from the new high-resolution STEM, which will provide unprecedented images of interface and growth phenomena, and from a new theoretical effort in massively parallel dynamical simulation of surfaces and interfaces using the ORNL Paragon supercomputer.

Research, instrumentation, and user-program-related preparations for the ANS project will be given a high priority. Superconductor research will emphasize continued use of unique materials preparation and characterization capabilities to investigate fundamental issues in critical currents and quantum behavior. Unique capabilities in high- (MeV) and low- (tens of eV) energy implantation, laser ablation, supersonic molecular beams, plasma processing, and nanophase materials preparation will form the basis for a new research thrust on the synthesis, processing, and fabrication of advanced materials. Progress in the development and application of submicrovolt-resolution X-ray diffraction and high-resolution surface spectroscopies will continue.

KC02 03—The Materials Chemistry Program • This program involves chemical synthetic approaches to advanced inorganic materials and emphasizes composition, purity, and morphology. Tailored inorganic and organometallic precursor compounds and polymers are being developed whose thermal or plasma-enhanced decomposition leads to nonoxide ceramics in thin film or fibrous forms. The discovery of novel synthetic approaches to transition metal nitride whiskers has generated a more general interest in morphostatic specific gas-solid reactions. Ion-implantation preparative techniques, photoacoustic spectroscopic characterization, and electrochemical behavior are being combined in fundamental studies of electrocatalysis by mixed-oxide overlayers on metals.

A dual focus exists in the area of nucleation, growth, and transport properties, the first being the development of an understanding of the nucleation and growth of precipitation processes of ceramic precursors. The second involves the development of reactors and reactions that will lead to the reproducible production of pure and mixed ceramic precursors. Because the transport properties of the species involved in these processes have theoretical and process importance, an effort is continuing for the measurement of diffusion coefficients and viscosities.

Oxide superconductors are being investigated in the program on thermodynamics and kinetics of energy-related materials. One principal effort is the determination of, and chemical thermodynamic modeling of, the oxygen nonstoichiometry of several of the superconductors. These studies are typically done over a wider range of parameters than those usually reported and provide information that is used by others for interpretation of characteristics such as crystal chemistry and electronic properties. Other efforts include determination of the conditions for stability of superconducting phases and the kinetics of synthesis processes. Such information can be used to control manufacturing processes. Close cooperation with similar efforts at ORNL and elsewhere is maintained to enhance the impact of the program.

Understanding the relationships among molecular structure, processing conditions, and performance properties of modern organic polymeric materials poses a unique challenge to structural chemists. Techniques being applied include neutron and X-ray scattering from both semicrystalline fibers and largely amorphous polymers and model compounds, neutron spectroscopy, thermal analysis, solid-state NMR spectroscopy, scanning-tunneling and atomic-force microscopy, and molecular dynamics simulations. Used in combination, these are revealing often unexpected microstructural and dynamic features, particularly in the semirigid parts of polymer systems.

A new initiative is testing a new theory of polymer interactions for nanoscale polymer blends; small-angle neutron scattering is the key experimental tool. This program benefits from the presence of an ORNL-UTK Distinguished Scientist.

KC03—Chemical Sciences • The Chemical Sciences Program supports the HFIR; the Radiochemical Engineering Development Center (REDC); and programs in atomic physics, basic chemistry, and chemical engineering.

The Atomic Physics Program at ORNL encompasses both experimental and theoretical investigations of a broad class of phenomena occurring when multiply-charged heavy ions interact with gases, solids, free and bound electrons, photons, and other ions. Within the Atomic Physics Program, ORNL currently operates the EN Tandem Accelerator, a user facility that provides a wide variety of light ions and multiply-charged heavy ions at energies up to several million electron volts per nucleon. Experiments requiring higher beam energies are conducted at the HHIRF. Members of the atomic physics group are also collaborating on a new series of atomic studies with ultrarelativistic heavy ions at CERN. At the other end of the energy spectrum, experiments of cross sections for inelastic collisions of multicharged ions with neutral atoms and molecules are carried out at the lowest attainable energies and are currently conducted using the ORNL ECR ion source. These studies emphasize characterizing the energy and angular distribution of ejected electrons. Proposed also is a new program to study details of ion-surface interactions. The electron-cyclotron resonance source and the HHIRF provide beams for merged-beam experiments. The merged-beams apparatus and the techniques currently being developed are applicable to the study of ion-atom chemical reactions involving unstable or reactive atomic species. An upgrade of the ECR source that will provide significantly improved performance for this facility has been funded (Table 5.4).

Table 5.4
Budget projections by fiscal year for the electron-cyclotron resonance source upgrade capital equipment
($ in thousands—BA)

	1991	1992	1993
Total funding	400	100	0

The atomic theory group has been significantly enhanced by the addition of an ORNL-UTK Distinguished Scientist. Areas of emphasis during this period will include applications of numerical techniques to atomic physics in the areas of low-energy ion-atom scattering, strong-field atomic physics, and chemical physics. Other initiatives include relativistic and quantum electrodynamics effects in atoms and investigations of the Coulomb three- and four-body problems. The KC03 Atomic Physics Program is also participating in the proposed Center for Computationally Intensive Physics described in the KB03 discussion.

Neutrons from the HFIR are vital to many research projects in the Material Sciences, Chemical Sciences, Magnetic Fusion, and Biological Sciences programs at ORNL and for users and collaborators from many universities, national laboratories, and industries in the United States and abroad. One of the prime purposes of the HFIR is to make research quantities of ^{252}Cf and other transuranium isotopes. The HFIR is unique in that it offers a combination of high flux with a mixed thermal/fission neutron spectrum, low irradiation temperatures, and flux tailoring. The facility is invaluable for neutron scattering, isotope production, and material-damage studies related to the Magnetic Fusion Program and to the design of other advanced reactor concepts such as the ANS.

Transuranium-element isotopes produced at the Radiochemical Engineering Development Center (REDC) are used throughout the world for basic physics and chemistry studies of the transuranium elements. They are also used in R&D programs relating to environmental effects, biological effects, and waste isolation. Basic chemistry studies of the actinides and transactinides emphasize the elements (curium and above) that are uniquely produced at the HFIR and the REDC or from HFIR products. The goal is the elucidation of the systematic trends in behavior of the characteristic 5f electrons progressing across these heaviest elements in the periodic table. Experimental approaches to define the chemical and solid state properties of these elements and their compounds include structural studies at high pressures and temperatures, characterization of unusual oxidation states in high-temperature vapors and nonaqueous solutions, and magnetic and heavy-fermion behavior at low temperatures. Solution properties are studied as an adjunct to the effective separation of the HFIR products. Fundamental mechanisms related to separations are studied by low-temperature matrix spectroscopy and other methods; emphasis is placed on exploiting photochemistry and coordination chemistry for separations purposes. State-of-the-art relativistic quantum mechanics calculations are carried out to complement experimental studies. Participation has begun in a multilaboratory initiative to establish a beamline at the LBL Advanced Light Source dedicated to actinide science; ORNL interest is focused on electronic characterization of gas-phase actinide species.

Part of the Analytical Chemistry Program moved in FY 1989 to the recently built Organic Chemistry Mass Spectrometry Laboratory at the Oak Ridge X-10 site. An Inorganic Chemistry Mass Spectrometry Laboratory is currently being constructed. Approximately $1 million in BES funds will be spent for new equipment for these two laboratories. This new facility will provide opportunities for collaborative research not previously available when much of the operation was housed at the Oak Ridge Y-12 Plant.

ORNL conducts fundamental research in various analytical concepts and methodologies:

- the use of lasers in advancing spectrochemical analysis,
- resonance-ionization mass spectrometry,
- glow-discharge mass spectrometry,
- gas-phase ion chemistry using mass spectrometry,
- ion-trap mass spectrometry,
- positron spectroscopy, and
- heavy-ion-induced X-ray satellite emission.

We have shown that, by levitating microdroplets in an ion-trap spectrometer, it is possible to detect a few molecules of fluorescent compounds by laser-based fluorescence spectrometry. We project an ultimate detection limit approaching one molecule of Rhodamine-6 G at a signal-to-noise ratio of 3.

A unique array of complementary experimental and modeling techniques is applied to study thermodynamics of interactions and reactions in highly nonideal aqueous solutions of electrolytes at high temperatures and pressures. The systems studied are selected for their fundamental significance and for their relevance to energy-related technologies including steam generation, nuclear and chemical waste disposal, the extraction of heat and mineral resources, and hydrothermal geochemistry.

Research in surface science/heterogeneous catalysis gives special emphasis to questions of surface structure and reactions involving sulfur-containing species on clean metals and surface alloys that serve as models for commercial hydrodesulfurization catalysts. The use of several ultrahigh-vacuum surface-structure approaches (including low-energy ion scattering) and surface-reaction approaches is being expanded by incorporation of synchrotron-based approaches to characterize molecular adsorbates.

An area of continuing emphasis will be obtaining new molecular-level knowledge concerning the organic chemical structure and reactivity of coals. These studies highlight the application of solid state NMR techniques to chemically modified coals and the use of surface-immobilized compounds to simulate diffusional restrictions during thermal and catalytic processing of coal. The information derived from these fundamental studies will contribute to the development of novel processes for the use of coal as a source of liquid fuels and chemicals.

Research on the kinetics of enzyme-catalyzed processes will concentrate on the fundamental physicochemical aspects of the conversion of light energy into chemical energy using artificial photosynthetic systems and the mechanisms associated with enzyme solubilization of cellulose and lignin. This research is directed at synthesizing a simplified photosystem capable of producing fuel from renewable resources and understanding the biomolecular optoelectronic properties of metallized photosynthetic membranes.

Chemical and physical principles underlying the design of more effective multiphase separation processes are being defined. The concept of molecular recognition is being applied in the design, synthesis, and evaluation of novel ligands for separating closely related metal ions by solvent extraction. Incorporation of complexing ability, charge-neutralizing ability, and organophilicity into single multifunctional extraction agents is currently stressed.

A major thrust in physical mass transport enhancement in fluid-fluid systems is the exploration of external field application. Emphasis is placed on elucidating, dispersion, coalescence, and stability phenomena in situations where high-flux fields are applied.

Additional initiatives lie in the areas of using high-gradient magnetic fields for macromolecular separations and in electro-enhanced vapor-liquid separations. Areas for future investigation include microwave enhancement of reaction/separation systems and geometric and external field effects in sorption, chromatography, and other solid-liquid processes. Fundamental, experimental, and theoretical studies of interactions of solvents, solutes, and surfaces relate macroscopic properties of solutions to intermolecular interactions and molecular correlation functions for challenging and important systems such as those characteristic of extraction by, and adsorption from, supercritical solutions. Such studies use methods such as distribution function theories, fluctuation theory, molecular simulations, and neutron scattering.

Many of the existing components of the KC03 basic chemistry program are well postured to contribute fundamental long-range chemical information relevant to the growing national emphasis on environmental remediation and protection and associated waste-related R&D, especially for aqueous systems. A program is under way to study the photochemical reactions and associated photophysics of aromatic molecules in atypical media such as aqueous solutions and sorbent solids. In addition to elucidating fundamental questions of photoreactivity in anisotropic environments, this work should contribute to understanding the transformation of hazardous materials in natural settings exposed to sunlight.

Continuing Initiative

Development of Melton Valley as a Strategic Resource for Nuclear and Radiochemical Technology

This initiative proposes to achieve significant synergistic advantages by integrating existing, planned, and new process facilities in Melton Valley into a focused major center that will support DOE's long-term nuclear and radiochemical R&D activities (Table 5.5).

New facilities developing in Melton Valley include the ANS; the Waste Handling and Packaging Plant; the Low-Level Liquid Waste Collection and Transfer System; and various radioactive and hazardous waste examination, storage, and disposal facilities. Existing and anticipated missions for the REDC, also located in Melton Valley, and for other parts of ORNL, include heavy-element production and purification; radioactive waste management R&D, fuel-cycle and fission-product research, and support of some of DOE's weapons activities.

Careful planning and development of a comprehensive center would optimize the value of large capital investments already planned in Melton Valley and would minimize the additional investments needed to sustain the radiochemical processing capabilities needed within DOE to support programmatic work. ORNL perceives this as a critical national need. Success in creating the proposed center would ensure continued capability to support DOE-ER missions at the HFIR/ANS. The REDC would provide extensive capabilities for R&D in support of DOE Office of Environmental Restoration and Waste Management (DOE-EM) decontamination

Table 5.5
Budget projections by fiscal year for the development of Melton Valley as a strategic resource for nuclear and radiochemical technology[a]
($ in thousands—BA)

	1993	1994	1995	1996	1997	1998
Total funding	500	500	1000	1000	2000	2000

[a]Funds are being sought from the Office of Energy Research under Program KC, Basic Energy Sciences, and from the Assistant Secretary for Nuclear Energy under Program AF, Nuclear Energy Research and Development.

and decommissioning (D&D) needs and, in resolution of other radioactive waste-related problems, would ensure the continued capability to perform DOE Office of Defense Programs missions currently under way and anticipated for the REDC, would provide enhanced educational opportunities to the next generation of scientists and engineers in radiochemistry and radiochemical processing, and would posture ORNL to support a resurgence of nuclear energy R&D within DOE. Development and expansion of nuclear and radiochemical capabilities within Melton Valley could also permit the eventual location of all of ORNL's hazardous facilities within that valley and away from the central Bethel Valley location.

Continuing Initiative

Center for Excellence in Research Reactors

A Center for Excellence in Research Reactors (CERR) has been proposed to DOE-ER and DOE-NE. The CERR will be an information gathering, processing, and distributing activity structured as an adjunct to existing research activities and reactor operations. A data base will be created to encompass research programs and reactor facilities throughout the United States. The CERR will conceptually serve as a bridging mechanism between the broad community of researchers who use research reactors and the research reactor operators. In addition, the CERR will serve as a catalyst for increasing mutually beneficial interactions within the research reactor operators' community. The following are three synergistic objectives of the CERR:

- To increase usage of research reactors by identifying innovative uses of these facilities and informing prospective user communities of opportunities available to them at these reactors. It will also promote modifications and/or additions to research reactors to improve the usefulness to the user communities.
- To provide technical support to research reactor users by creating and maintaining a data base on user-oriented features. It will also maintain software systems and will involve technical personnel who could perform some technical analyses for the users and provide specialist contacts on specific issues.
- To foster excellence in research reactor operations by stimulating exchanges of "good practices" and "lessons learned" among the reactor operators and by encouraging operators to participate in "common element" activities. As an example, the CERR will support research groups in interactions with existing operational groups (such as the Association for Excellence in Reactor Operations) that are focused on promoting excellence in all aspects of operations.

These objectives can be accomplished by a relatively modest effort (two FTE staff members per year) to compile and to provide user-oriented information about research reactor facilities and to stimulate mutually beneficial activities within the research reactor community. The CERR concept will build on strengths in existing research reactor activities at ORNL, other DOE sites, and non-DOE facilities and will strive to bring positive benefits to both the research reactor user community and the research reactor operations community.

Research reactors have been a vital part of the early development of many fields of nuclear science and engineering, and those same reactors were essential to the development of nuclear energy throughout the world. Nearly 100 research reactors were built in the United States during the 1950s and 1960s, but more than half of these already have been shut down. Many others may be closed in the near future because of decreased use during the last decade, inadequate funding for modernization, and more rigorous operating requirements. The continued rapid loss of research reactor facilities could seriously impact future research programs in numerous technical disciplines.

Traditional uses for research reactors are expected to continue (for example, neutron radiography, activation analysis, medical isotope production, biomedical irradiations, materials studies, and commercial product preparations). In addition, much more exciting work is yet to be done including, for example, research in advanced ceramics and high-temperature superconductors. Furthermore, the uses of reactors in experimental research could increase significantly if an effort is made to identify potential users and to inform them of the current availability of the reactor facilities. The decline of interest in nuclear power reactor technology during the 1970s, the permanent closure of many research reactors during the 1970s and 1980s, the shutdown of ORNL and other DOE reactors for exhaustive reviews in the late 1980s, and the announced shutdown of others to occur in the early 1990s—all of these factors have left researchers seeking facilities that can provide the proper combination of radiation fields, sample space, temperatures, and other parameters for their experiments.

The continued decline in the number of research reactors in this country and the growing need for such facilities in the future present a real national dilemma. One of the factors contributing to this dilemma has been the lack of any institution having the purpose or the resources to identify the existing and projected needs of the user community for research reactor facilities and to develop an integrated strategy ensuring that these needs could be met. Many researchers do not have a reliable source of information about reactor facilities, and because of the Laboratory's reputation in reactor-based research, they often call ORNL personnel for help in locating a reactor that is appropriate for their experiments.

The organization of a CERR is a positive step toward reestablishing U.S. leadership in nuclear technology. Specific activities of this program will include

- determining existing and projected user needs for research reactor facilities;
- collecting, analyzing, evaluating, and maintaining data on existing research reactor facilities relative to current and projected user needs;
- developing a unified strategy for establishing and maintaining a viable network of research reactor facilities;
- establishing and maintaining a regional center at ORNL to meet possible needs of the user community and to stimulate new and expanded use of research reactors (similar centers may be established in other regions); and
- establishing and maintaining a regional center at ORNL to promote excellence in all aspects of ORNL research reactor operations.

A CERR should encompass all U.S. research reactors at both universities and national laboratories and should involve individuals from throughout the entire nuclear technology community including representatives of industrial users.

ORNL is especially well suited to initiate a CERR because of (1) the existing strong commitment to excellence in operation of research reactors, (2) an established history of providing technical support for reactor users, and (3) the presence within ORNL and the vicinity of a diverse community of research reactor users. This unique combination of conditions does not exist at any other DOE site. The successful implementation of a CERR will prove very beneficial to the research community in that access to research reactors will be enhanced and more cost-effective. The reactor operators will benefit from increased utilization of facilities and from cost-effective improvements in operating standards. The CERR will greatly expand educational opportunities for students and for professional staff members of national laboratories, private companies, and governmental agencies and will provide an effective channel for transferring technology from government-sponsored research programs to private industries.

The proposed program will require significant initial effort. Our aim is accomplishment of the first three objectives within the program's first year. Beginning in the second year other regional centers could be established as institutional entities whose purpose would be to further increase communications and interactions with the user community. The CERR will have no provision for any operational responsibilities for the reactors; the full responsibility for operating each reactor in compliance with respective orders or regulations must remain with the owners/operators. The CERR will stimulate increased usage of the reactors and help make the facilities more user friendly. Table 5.6 provides budget projections for the ORNL CERR. They are also included in the ORNL April 1992 budget submission summarized in the "Resource Projections" section (Table 10.5).

Table 5.6

Budget projections by fiscal year for ORNL's Center for Excellence in Research Reactors[a]

($ in thousands—BA)

	1993	1994	1995	1996	1997	1998
Total funding	0	393	411	430	450	470

[a]Funds are being sought from the Office of Energy Research under Program KC, Basic Energy Sciences, and from the Assistant Secretary of Nuclear Energy under Program AF, Nuclear Energy Research and Development.

New Initiative

Retention of the Pool Critical Assembly

A proposal has been made to DOE to retain use of the Pool Critical Assembly (PCA) so that it can be used in support of training and education activities for a broad range of users, including UT, Louisiana State University, Mississippi State University, ORAU, and DOE, in support of its mathematics and science education initiatives.

From 1957 until 1985, PCA provided hands-on educational experiences to nuclear and military professionals. The PCA's simple, basic structure lends itself to easy comprehension of fundamental reactor principles from an education or training perspective. The following training experiences are possible at PCA:

- hands-on core assembly;
- hands-on reactor startups and shutdowns;
- reactivity determinations;
- spatial dependence measurements of neutron absorber worth, neutron importance, and power density;
- neutron spectral measurements; and
- neutron activation analysis.

A PCA restart plan will be utilized and will contain a work breakdown structure that will detail all tasks required for restart. Funding has been requested to relocate, restart, and operate PCA in support of the mathematics and science education initiatives advocated by DOE in SEN-23-90. The PCA will also be utilized to train DOE Reactor Operations professionals, nuclear industry personnel, and nuclear-engineering students. Restart activities will require funding in FY 1994 and FY 1995 (Table 5.7). After restart in FY 1996, operations will require about $300,000 annually, part of which will be provided by the HFIR training section.

Table 5.7

Budget projections by fiscal year for ORNL's Retention of the Pool Critical Assembly[a]

($ in thousands—BA)

	1993	1994	1995	1996	1997	1998
Total funding	0	550	682	417	330	340

[a]Funds are being sought from the Office of Energy Research under Program KC, Basic Energy Sciences, and from the Assistant Secretary of Nuclear Energy under Program AF, Nuclear Energy Research and Development.

It is proposed to relocate the PCA to Building 7930 of the REDC at ORNL. The fuel and core assembly will occupy an 8- by 12-ft area in the north end of an existing californium storage pool. A 1200 ft^2 annex will be required to house training facilities, work areas, and the PCA control room. Funding for the control room annex will be requested utilizing GPP monies. The PCA will become a part of the REDC Complex; however, REDC will not provide any funding, and a fair share of utility usage and pool demineralization costs will be paid by PCA.

PCA-enhanced training programs will provide benefits of increased professional capabilities for students as well as for nuclear specialists.

KC04—Engineering and Geosciences • The major effort supported by the engineering component of the Engineering and Geosciences Program is the Center for Engineering Systems Advanced Research (CESAR). One new engineering initiative is a proposed study of advanced bioprocessing systems for energy production and conservation. An initiative is in preparation that will focus on the elucidation of the theory of interactions for multibody problems in external fields. The effort will center on nonlinear approaches and will emphasize the application of parallel computation in these systems. This will be the centerpiece of a collaboration between ORNL and the University of California at Berkeley.

The CESAR Project will continue autonomous mobile robot research [the Hostile Environment Robotic Machine Intelligence Experiment Series (HERMIES)] using the small HERMIES-IIB test bed and the recently constructed HERMIES-III, which has significant manipulation capabilities. Funding is expected to increase slightly during the reporting period. New areas of emphasis include the combined use of sensor-guided manipulators and platform mobility and the control and allocation of heterogeneous resources (e.g., multiple cooperating autonomous robots). A collaborative venture with the French Atomic Energy Association will involve a performance comparison of algorithms, software, and hardware used in computer simulations and on mobile robots. The collaborative research environment and facilities at CESAR continue to attract faculty and students from universities in the United States and overseas (e.g., Belgium, Japan, and South Korea).

The recent DOE emphasis on waste R&D research includes the role that artificial intelligence and robotics might play in this multidisciplinary effort. CESAR is uniquely positioned to contribute to this initiative because of its focus since 1984 on the R&D of robotic intelligent machines for operation in hazardous, unstructured environments. Existing relationships with the decontamination and decommissioning effort at the Oak Ridge K-25 Site and ongoing collaboration with the robotics technology development and integration effort for environmental restoration and waste management show that the long-term CESAR commitment to basic R&D in intelligent machines results in the ability to react and to contribute quickly to the solution of pressing applied problems. Under the Space Defense Technologies and Robotics and Intelligent Systems programs, ORNL staff will provide program coordination and technical leadership for the robotics element of a DOE space effort.

The Geosciences Program concentrates on the fundamental geochemical processes that control elemental and isotopic distributions in the earth's crust. Special facilities for study of high-temperature aqueous and magmatic systems are used to study metal-ion complexing by carboxylates, mineral solubilities and crystallization, stable isotope exchange with minerals, and the thermodynamics of the carbon-hydrogen-oxygen system at extreme conditions. Experimental data are used to model the evolution of natural systems pertinent to DOE geothermal and hydrocarbon energy programs. New acoustic imaging methods for subsurface and magmatic environments are being developed. A unique ion-microprobe capability to conduct isotope distribution studies is being applied to mineral assemblages.

KC05—Advanced Energy Projects • The Advanced Energy Projects Program supports exploratory research in materials and chemical science at moderate levels, typically for 3 years' duration. Initiatives include projects in electric-field-driven ceramic precursor reactors, the development of oxide particulates for use in evacuated insulating panels, the elucidation of enzyme hydrolysis mechanisms waste-paper conversion to chemicals, and novel composite coatings for high-temperature friction and wear control.

KC07—Applied Mathematical Sciences • The Applied Mathematical Sciences Program supports research in parallel-processing algorithms and the development of applied mathematical, statistical, and computational methods for analyses of physical processes. These research activities are supported by an Advanced Computing Laboratory that provides research computers with a variety of architectures in various stages of development. Parallel computers currently in the Advanced Computing Laboratory include an Intel Beta, an Intel iPSC/2, an nCUBE/4, a Sequent Balance 8000, a Cogent multiprocessor workstation, and an Intel iPSC/860 supercomputer. The latter item has 128 processors and a peak rating of 7.6 gigaflops.

The following will continue to be major research areas: sparse matrix computations, performance characterization, basic matrix computations, design and analysis of computational experiments, and the analysis and numerical solution of partial differential equations. Pervasive in this research is the requirement for parallel processing and related software tools to meet the computationally intensive needs of today's computer models. A continuing initiative for ORNL that is heavily dependent upon the KC07 Program is the Grand Challenges in Computational Science. (See "Center for Computational Science" in Sect. 4.)

Groundwater modeling is one of the grand challenges selected by DOE because of its importance in evaluating groundwater-contamination and groundwater-remediation strategies. New groundwater codes will be developed on parallel computers that allow greater complexity in processes as well as scale. By examining site-specific problems, different simplifying assumptions can be tested and different remediation strategies can be evaluated. These are important steps in saving time and cost for groundwater cleanup by picking effective modeling and remediation techniques. The expertise developed in the Applied Mathematical Sciences Program will be one of the key foundations for developing this initiative. The second Grand Challenge problem that is already in place is in the First Principles Simulation of Materials Properties. The goal is to allow existing quantum and statistical mechanics codes currently restricted to tens of atoms to be scaled up to thousands of atoms. This scaling will require the use of sophisticated numerical techniques that scale up as the cube of the number of atoms.

CHAMMP, the new DOE initiative in KP05 Atmospheric and Climate Research Division, will benefit from the basic program in KC07 and will drive some of its future research activities. The initiative requires new parallel-computing research in numerical methods; software tools; software engineering; statistical analyses; and data storage, retrieval, and visualization. ORNL's researchers in the KC07 and KP05 programs will work closely together to draw upon required expertise.

KD—Energy Research Analyses

ORNL supports the DOE-ER in technical and economic assessments of alternative energy sources for selected sectors of the U.S. economy. The funding level varies according to the specific needs of DOE but is expected to remain relatively stable. During FY 1992, ORNL provided support for the Office of the Secretary of Energy Advisory Board and the Office of Energy Research in technical review of DOE research programs. Future technical and analytic support for assessments of programs will be provided as requested. ORNL anticipates providing support for analysis of global climate change issues and new analyses in support of the reauthorized National Acidic Precipitation Assessment Program.

KG—Multiprogram Energy Laboratories Facilities Support

The DOE Multiprogram Energy Laboratories Facilities Support Program provides funding for general-purpose, line-item construction projects at ORNL. General-purpose facilities include facilities such as office, laboratory, and shop buildings housing administrative and Laboratory-wide support functions, utility systems, and roads that relate to many programs. Line-item construction projects are those with a total estimated cost of $1.2 million or more.

ORNL has a large backlog of facilities deficiencies for which a number of corrective construction projects are proposed. See the "Site and Facilities" section (Table 9.2) for a more complete description of ORNL's facilities needs along with a complete list of proposed line-item construction projects that include those being submitted to this program.

KP—Biological and Environmental Research

Goals of the KP Program are (1) to study the interaction of energy-related physical and chemical agents with living organisms and the environment including their transport, chemical transformations, adverse health effects, and ultimate consequences to humans and the environment; (2) to contribute to DOE's Nuclear Medicine Program and other beneficial applications programs; and (3) to transfer research findings and technological developments outside ORNL. Research areas in biology include mammalian genetics, molecular genetics, protein engineering, cell biology, carcinogenesis, macromolecular structure, mutagenesis, and risk assessment. Environmental science research covers biogeochemistry, environmental biotechnology, global environmental chemistry, ecosystem studies, geosciences, hydrology, environmental assessment, theoretical ecology, and landscape ecology. Health and safety research encompasses human health analysis, epidemiology, health assessments, radiation and chemical physics, dosimetry, nuclear medicine, and instrumentation development for sensitive detection and monitoring of chemicals. In addition, two unique user facilities are supported by the KP Program: the Oak Ridge National Environmental Research Park and the BRF. Users of these facilities include staff members of national laboratories and industries, and students and staff members from universities.

The ORNL KP Program is one of the broadest multidisciplinary life sciences research programs in the nation and covers a diverse range of both basic and applied studies. Overall, the KP Program at ORNL is expected to experience growth in global change research, subsurface sciences, molecular and mammalian genetics, human genome research, structural biology, and human health effects studies in this planning cycle.

KP01—Analytical Technology-Dosimetry Research and Measurement Science • One of the important tasks of this activity is the development of radiation exposure-dose relationships through modeling the biokinetics of radionuclides within the body and modeling the deposition of ionizing energy within radiosensitive tissues from these radionuclides and from radiation externally incident upon the body. Such exposure-dose relationships compose the cornerstone of radiation protection and serve an important role in the evaluation of medical diagnostic procedures involving use of radiopharmaceuticals and X-ray machines.

Development of models describing the biokinetics of radionuclides in persons other than a hypothetical young adult male has required a substantial departure from the traditional empirical approach of "curve fitting" of data from a limited number of exposed individuals. As far as is practical, the models currently being developed explicitly depict the tissues and physiological processes controlling the movement or retention of radionuclides in the body. The advantages of a physiologically realistic approach are that it allows (1) incorporation of basic physiological information into the model, (2) realistic treatment of decay products formed in the body, (3) meaningful extrapolation of data from laboratory animals to humans, (4) meaningful analogies between an element of interest and physiologically similar elements, and (5) a linkage between excretion of a radioactive element and movement among body tissues and blood. Biokinetic models, along with age-specific dosimetric models, developed by this work are featured in the first report of the International Commission on Radiological Protection (ICRP) that tabulates data on the organ dose per unit intake for individuals of various ages. Extensive participation by ORNL staff on committees and task groups of the National Council on Radiation Protection and Measurements, the Medical Internal Radiation Dose Committee of the Society of Nuclear Medicine, and the ICRP provide recognition of the scientific expertise in this program. Another effort under this activity involves multidisciplinary research targeted toward three major areas: (1) cost-effective chemical and biological screening techniques, (2) biological and chemical sensors, and (3) basic technical advances of emerging monitoring technologies.

A continuous monitor for formaldehyde in indoor air has been developed. The device is inexpensive because sensors placed throughout a building are multiplexed through optical fibers to a single light source and detector. Individual sensors measure the color produced when formaldehyde reacts with a chemically selective reagent. Formaldehyde can be detected at levels below OSHA-regulated concentrations, and there is no interference from different aldehydes or other common chemicals found in the indoor environment.

We have initiated the development of the second-generation fluoroimmunosensor (FIS). The previous FIS devices were developed for "one-shot" measurements, while the second-generation FIS devices are designed to be regenerable. By combining FIS technology with a capillary reagent delivery system, we have constructed microscale sensors that are capable of performing a variety of heterogeneous FIS procedures repetitively, remotely, and in situ (Fig. 5.8). These procedures include adding a solid- or liquid-phase antibody, adding secondary reagents (e.g., the labeled "second" antibody when performing sandwich assays), and rinsing to remove unbound impurities. In addition to delivering reagents, the sensor has the capability of sampling analytes through a membrane via either diffusion or aspiration. The latter mode of sampling could be very beneficial in the eventual use of the sensor for the measurement of large molecules.

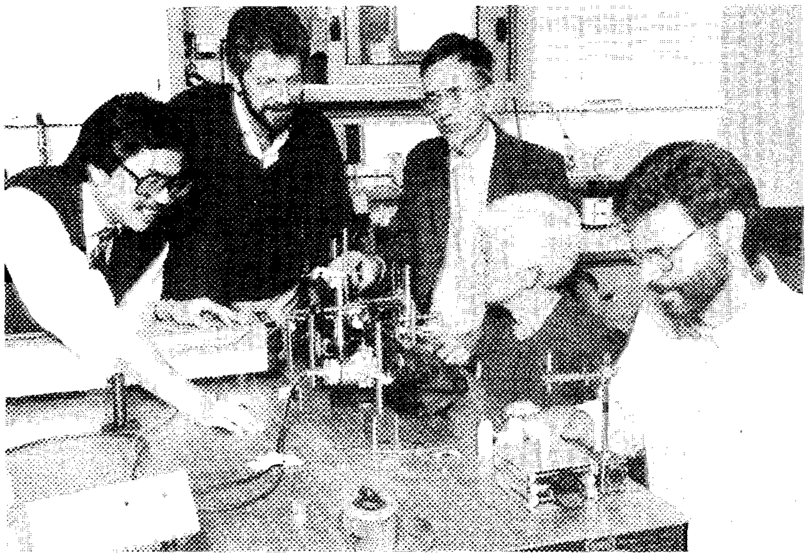


Figure 5.8
Scientists at ORNL and the University of Tennessee have developed an antibody-based fluoroimmunosensor that can be used to detect attomoles (10^{-18} moles) of biochemical compounds. This device, an R&D 100 winner, can have a wide range of applications in biotechnology, cancer diagnostics, and structural biology research. The researchers are (left to right) T. Vo-Dinh, M. J. Sepaniak, G. D. Griffin, K. R. Ambrose, and B. J. Tromberg.

Other instrumentation development is directed toward a portable luminscope for low-cost field screening of polychlorinated biphenyls (PCBs) and a dosimeter for continuous monitoring of chemical warfare agents.

ORNL researchers have international recognition in neutron dosimetry. Annual international personnel neutron dosimetry intercomparsion studies at the Radiation Calibration Laboratory (RADCAL) are a major focus of technology transfer. RADCAL has been outfitted with radioisotopic sources and an X-ray machine configured to deliver precise doses at specified locations. The major emphasis of research is on personnel radiation dosimetry, but RADCAL is also involved with nuclear accident dosimetry, radiobiology research, national dosimeter performance test programs, teaching and training activities, and dosimeter intercomparison studies expanded to include beta, gamma, and X-irradiation as well as neutrons.

A broad-based research program in the HASRD is directed toward increasing our knowledge of detrimental effects of all types of energy production. Included in this program are research on chemical, biological, and physical agents associated with energy technologies; development of advanced measurement techniques; and development of appropriate assessment and risk-analysis methodologies needed to make balanced estimates of current and future energy strategies. Using software developed by the Geographic Data Section of the Computing and Telecommunications Division, researchers can examine images of organs of interest to define their shape, size, location, and density. These data are used in radiation transport calculations using Monte Carlo methods to compute the deposition of ionizing energy in radiosensitive organs and tissues of the body from medical and environmental radiation exposures.

KP02—Environmental Research • The goal of the KP02 Program is to increase our understanding of the transport, transformation, and effects of energy-related contaminants in the environment. To gain a greater appreciation of the fundamental biological, chemical, and physical processes governing the transport and effects of materials in the environment, linkages among the atmosphere, the terrestrial biosphere, and fresh water systems are emphasized. Basic studies in radon dynamics focus on subsurface source and transport mechanisms.

Environmental Biogeochemistry • The ORNL atmospheric research project concentrates on quantifying several aspects of atmosphere/biosphere exchange that are critical in understanding and predicting the effects of global change. These include wet and dry removal processes and surface emission rates of both natural and pollutant constituents important to tropospheric chemistry and biogeochemical cycling. Major emphasis is placed on determining the interactions of these materials with forest canopies, particularly in complex terrain. New issues in the planning stage include testing and application of throughfall methods for quantifying terrain and canopy controls on deposition in mountain forests and developing and testing methods and models of mercury vapor interactions with land and water surfaces. This work supports DOE tasks in the areas of dry deposition, precipitation scavenging, deposition modeling, landscape scaling, biogenic emissions, and biogeochemical cycles.

Transport studies involve the measurement of naturally occurring radionuclides (^{7}Be, ^{35}S, and ^{210}Pb), anthropogenic radionuclides (^{137}Cs, ^{239}Pu, and ^{240}Pu), and stable isotopes (^{13}C, ^{15}N, ^{2}H, ^{3}H, and ^{18}O) to trace and quantify the dispersal and fate of energy-related materials, as well as fixed carbon, in watershed, estuarine, and ocean-margin systems. The watershed research is focused on identifying groundwater and surface water sources and on quantifying the extent to which atmospherically derived substances such as sulfur and lead biogeochemically interact with drainage-basin soils and vegetation during runoff or snowmelt. The marine research is focused on using biogeochemical tracers to quantify the exchange of materials between the land and sea, between continental shelf and slope, and between sediments and water column. Planning and scientific exchange between the Institute of Energy Problems and Chemical Physics and the Institute of Oceanology of the Russian Academy of Sciences and ORNL has been under way since 1991 to develop a joint research program to investigate biological and biogeochemical effects of increased ultraviolet radiation on marine ecosystems. ORNL-led studies within the program framework include assays for DNA damage in phytoplankton that can be attributed directly to ultraviolet B (UV-B) radiation as well as changes in biogeochemical cycling as traced using radioisotopic tracers and stable isotopes. This program will use ship support from the Russian Academy of Sciences in 1992 and 1993 and is designed to take advantage of the complementary and unique skills of each organization involved. This research is important for three reasons: (1) for developing predictive capabilities to assess (over large spatial and temporal scales) the net movement and biogeochemical fate of substances associated with energy-development and waste-disposal activities, (2) for determining their potential effects on terrestrial and marine ecosystems, and (3) for evaluating rates of transfer and cycling of carbon between various reservoirs that may be influenced by global change.

Radon • The subsurface source, transport, and entry of radon-bearing soil gas into residences is a critical component of environmental radon dynamics. HASRD continues to study relevant mechanisms pertaining to houses and geology in the southern Appalachians with funding from OHER. These studies are designed to gain insight into climatic, seasonal, and spatial fluctuations of indoor radon concentrations. These studies are important to efforts to identify efficiently those structures in most need of remedial action. As a consequence of these and earlier studies, ORNL staff have developed widely recognized expertise in the mitigation of elevated radon levels in housing and administrative buildings. In the past 2 years, staff members have been invited by the Air Force and the Navy to train their personnel in these principles at sites ranging from Guam in the Pacific to Bermuda in the Atlantic. Other agencies, including DOE, have expressed interest in our findings and expertise.

Ecosystem Function and Response • Environmental Sciences Division research for OHER focuses on biogeochemical cycling at the watershed scale; Walker Branch Watershed is a central research facility. Research also addresses atmospheric-deposition inputs, subsurface hydrologic transport, element cycles, and effects in streams. Our research on the physiological ecology of terrestrial vegetation is an integral component of the Walker Branch Watershed Project. The scientific goals of the Walker Branch Watershed Project directly coincide with the type of research identified by OHER as being a critical national R&D need. In particular, one of OHER's missions is to understand the physical, chemical, biological, and geological processes that directly and indirectly control the flux of energy-related contaminants from their sources through the environment to sensitive receptors or long-term sinks. The Walker Branch research focus is on the spatial and temporal variations in mechanisms that regulate the storage, transformation, and transport of critical ecosystem resources such as carbon, nitrogen, and phosphorus (Fig. 5.9). A Major new initiative is a

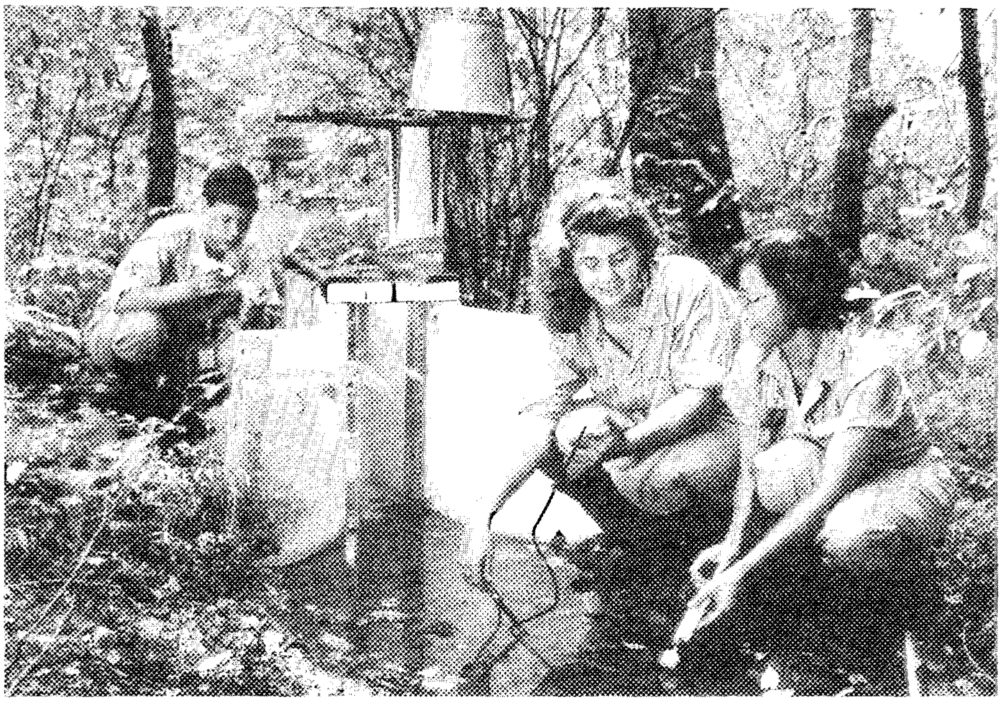


Figure 5.9 Bonnie Lu (right) and participants in the DOE High School Honors Program in Environmental Sciences measure electrical conductance and filter water from a stream discharging into Walker Branch on the Oak Ridge Reservation. Researchers measure the concentrations of chloride, nitride, and phosphate in the filtered water as part of an experimental tracer study to determine the pathways of groundwater flow and the potential for nitrate removal from the stream.

large-scale rainfall-manipulation experiment to investigate the effects of climate change on critical ecosystem processes in deciduous forests. Research on vegetation response to air pollution stress (particularly O_3, SO_2, NO_2, and acid deposition) has achieved national prominence. Our research efforts encompass the role of terrestrial-aquatic linkages in the processing of atmospheric pollutants and changes in stratospheric ozone and the effects of UV-B on biotic resources in terrestrial and aquatic systems. As is the case in most technology-related pollution problems, an interdisciplinary approach is required for planning and conducting the appropriate research.

National Environmental Research Park • The Oak Ridge National Environmental Research Park is directed to include networking with the other five DOE parks through the ParkNet System. Park goals focus on

- integration and synthesis of existing data across parks, including site-characterization data collected as part of the Environmental Restoration Program;
- coordination of activities among parks;
- on-site data management and data organization (including establishment of computer data bases of historic data) and coordination with the Oak Ridge Reservation Environmental Information Systems DOE waste-management activities;
- activities promoting the parks as a coordinated network of cooperating research sites; and
- ParkNet leadership in the disciplines of landscape ecology, remote imagery applications, and species diversity.

In January 1989 the Oak Ridge Research Park was formally chartered as a component of the Southern Appalachian Man and Biosphere Reserve. Park activity provides special leadership in the region on biodiversity, climate change, environmental education, and acid deposition. As directed by DOE, no research or data collection is funded by the Oak Ridge Research Park. The FY 1991 DOE budget for the park was $125,000; this supported an individual to respond to ParkNet inquiries, to sponsor remote imagery workshops, to organize files on existing environmental data, to travel to Research Park meetings, and administratively to manage and monitor activities on the 5008 ha. As is noted in Sect. 7, "Contributions to Economic Competitiveness," (Guest Research and User Facility programs), ecological and environmental health visitors conducted thousands of user days of environmental research, monitoring, and restoration activities in the park during FY 1990. Extensive and assorted data on the park can provide a rich resource if automation and retrieval is prioritized and focused on key issues. Alternative sources of funding have been under consideration to develop and to actuate a central plan consistent with Research Park objectives. Climate change, environmental restoration, environmental risk, and sustainable systems are some alternatives under consideration. Very recent activities that have been conducted at the park but not funded by the park include administration of wildlife management (deer hunts, turkey and osprey restoration, and pest management), wetlands surveys (Fig. 5.10), herbarium development, and rare plant surveys and management. More theoretically based research funded by DOE, Electric Power Research Institute (EPRI), and EPA support has addressed nutrient dynamics and ion chemistry studies on the Walker Branch Watershed, stream biological diversity evaluations, high school honors summer research projects, studies of greenhouse gas effects on tree growth, and workshops on data sharing with the other biosphere components of the Southern Appalachian Man and Biosphere. Other studies have evaluated forest fragmentation and recovery, forest responses to drought, stream fauna population dynamics, and effects of geomorphology on potential contaminant subsurface transport. Test wells are monitored throughout the site. In addition, various forms of remote imagery have been integrated with ground data using Geographic Information System technology for portions of the park.

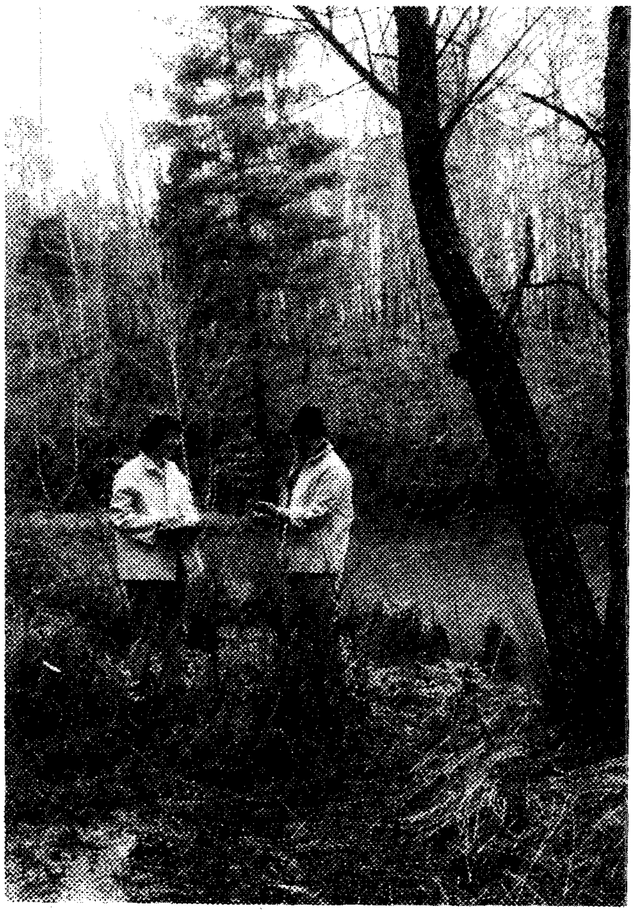


Figure 5.10 Larry Pounds and Rebecca Cook classify plant species growing in a wetland on the Oak Ridge Reservation. As part of an ongoing project, they will use this information along with soil samples and hydrologic data to identify the boundaries of wetlands so that activities planned on the reservation can be directed away from these federally protected areas.

Theoretical Ecology • Research efforts will increase on quantification of regional landscape patterns and the processes affecting ecosystems at large spatial scales. Our theoretical research has explored some basic properties of scaled systems with a view toward taking advantage of the scaled structure in predicting system dynamics.

Theoretical and modeling studies are designed to develop methods for measuring ecological patterns of natural and managed landscapes, relating these patterns to processes, and estimating how these patterns will change as a result of broad-scale disturbances. A major challenge of this work will be the careful development of statistical approaches to the analysis of spatial patterns. New emphasis will be placed on testing and on validation of theory and models through the use of field and remote-sensing data available from the Research Parks and through collaboration with other agencies (e.g., the National Park Service and the EPA's Environmental Monitoring and Assessment Program).

Continuing Initiative

Advanced Photonics for Environmental Needs

Fueled by the growing global concern over environmental insults, a critical need has developed for the next generation of instrumentation to have a high degree of sensitivity, selectivity, and portability. These needs arise in quantitative studies of waste generation, transport, and remediation, as well as global atmospheric problems such as the world energy balance (greenhouse effect), the ozone depletion problem, and the study of airborne pollutants. For instance, the DOE's new Atmospheric Radiation Measurement Program will require state-of-the-art remote-sensing instrumentation. Photonics instrumentation, particularly instrumentation involving novel lasers and newly discovered physical principles, is capable of providing "single-atom sensitivity" and isotopic, atomic, or molecular selectivity. Furthermore, photonics devices are becoming more compact, field-hardened, and in the case of lasers, capable of remote application. Table 5.8 summarizes budget projections for this initiative.

ORNL's Health and Safety Research Division is a leader in developing and using laser technology to study fundamental chemical and physical processes. Responding to the needs of both environmental scientists and waste cleanup specialists, many of these new techniques can be focused on applied measurements. As examples, two ongoing instrumentation development programs are directly linked to needs of ESD. One has involved a device to measure UV-B penetration in leaves; the other, a sensitive optical mass spectrometer for measurement of organics in forest canopies. A third proposed device for laser remote sensing of atmospheric species would address the measurement of greenhouse gases. This initiative is interdisciplinary (chemistry, physics, and environmental science) as well as interdivisional in its contribution to solving urgent national problems. This activity is part of a larger Laboratory-wide Photonics Initiative being developed by several ORNL research divisions under the auspices of the recently formed ORNL Advanced Photonics Working Group.

Table 5.8

Budget projections by fiscal year for Advanced Photonics for Environmental Needs Initiative[a]

($ in millions—BA)

	1993	1994	1995	1996	1997	1998
Total funding	0.7	0.8	1.0	1.2	1.5	1.8

[a]Funding is being sought from the Office of Energy Research under Program KP, Biological and Environmental Research.

New Initiative

Biological Imaging and Analysis Center

Recent years have brought a revolution in microscopy through the introduction of electron scanning-tunneling microscopes (STMs), atomic force microscopes (AFMs), and photon scanning-tunneling microscopes (PSTMs). The PSTM is also capable of performing high-resolution optical spectroscopy and can carry out chemical mapping with spatial resolution previously unattainable. The STM has produced topographical mapping on an unprecedented scale (Fig. 5.11). The STM has produced topographical images of DNA and its base pairs on conducting substrates, while the AFM has performed similarly for samples on mica (Fig. 5.12). Several hybrid versions of these instruments are on the horizon, and significant breakthroughs in biological imaging and analysis can be expected.

ORNL has made pioneering contributions to this field, including the invention of the PSTM. Future research will include development of methodologies for a broad range of biological samples

Figure 5.11
A scanning tunneling Microscope (STM) image of an open circular pBS+ plasmid DNA molecule chemically bound to a gold surface with a thiol compound

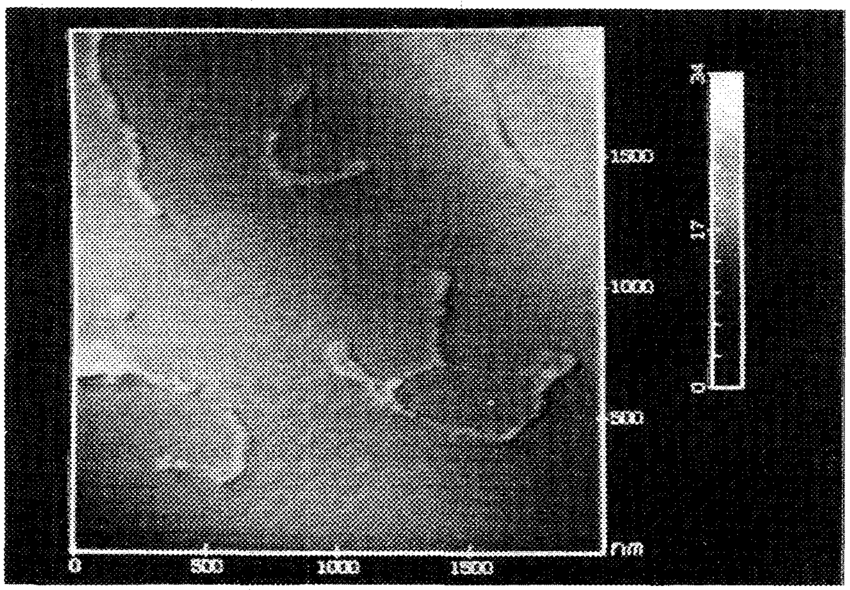


Figure 5.12
Atomic force microscope (AFM) images of pBS+ plasmid DNA on freshly cleaved mica

and development of hybrid instruments for chemical mapping. Also targeted for investigation is the use of combined infrared and optical spectroscopy for chemical mapping of biological samples using the PSTM. Table 5.9 summarizes budget projections for this initiative.

Table 5.9
Budget projections by fiscal year for the Biological Imaging and Analysis Center[a]
($ in millions—BA)

	1993	1994	1995	1996	1997	1998
Total funding	0.9	1.0	1.1	1.2	1.2	1.2

[a]Funding is being sought from the Office of Energy Research under Program KP, Biological and Environmental Research.

Continuing Initiative

Subsurface Science Research

We will continue our work in the areas of hydrology, geochemistry, modeling, and colloid chemistry in support of DOE programs in site-directed subsurface transport of hazardous substances and subsurface microbiology. Additionally, we will increase efforts related to heterogeneity of the geological, hydrological, and microbial components of the subsurface environment and will initiate efforts related to the origin or transport of microbes in the deep subsurface. Research in subsurface sciences is directed toward defining, understanding, and predicting the movement of energy-related contaminants in humid regions with highly organic natural waters. In direct response to the accelerated efforts on the part of DOE to address the characterization and eventual cleanup of contaminated facilities, this work is expected to grow significantly because it will represent an essential element in the waste R&D plans (Table 5.10). At present, activities at ORNL consist of laboratory and field studies that are integrated with the development and application of hydrologic and chemical transport models. These studies involve research on the role of colloids and microbial populations in affecting subsurface transformation of energy byproducts (including mixed wastes), modeling of the spatial heterogeneity of soils, and research on the thermodynamic and kinetic parameters important to contaminant migration at DOE sites. These, as well as new initiatives that are responsive to DOE's waste R&D plans, will continue and will provide a unique and sound foundation for understanding subsurface contaminant migration in a humid environment (Figs. 5.13 and 5. 14).

Table 5.10

***Budget projections by fiscal year for the Subsurface Science Research Initiative*[a]**

($ in millions—BA)

	1993	1994	1995	1996	1997	1998
Operating expense	5.7	6.3	7.0	7.3	7.5	8.0
Capital equipment	0.8	0.9	1.0	1.0	1.0	1.0

[a]Funding is being sought under Program KP, Biological and Environmental Research.

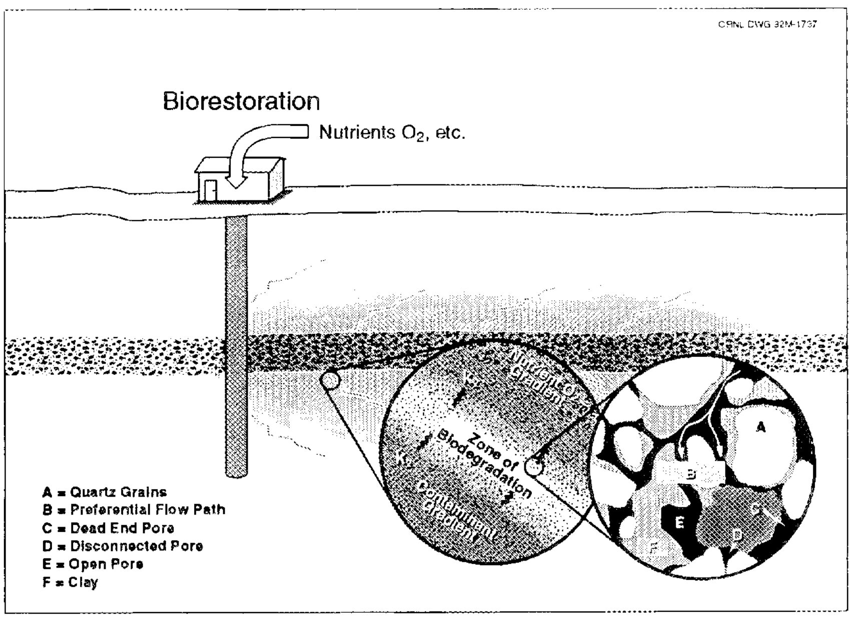


Figure 5.13 Effective application of in situ bioremediation requires consideration of the critical issues of scaling and heterogeneity. Strategies to enhance biodegradation by native microorganisms through the delivery of nutrients or electron acceptors (such as oxygen) are limited by diffusion of the treatments from highly transmissive zones into the finer pore structures.

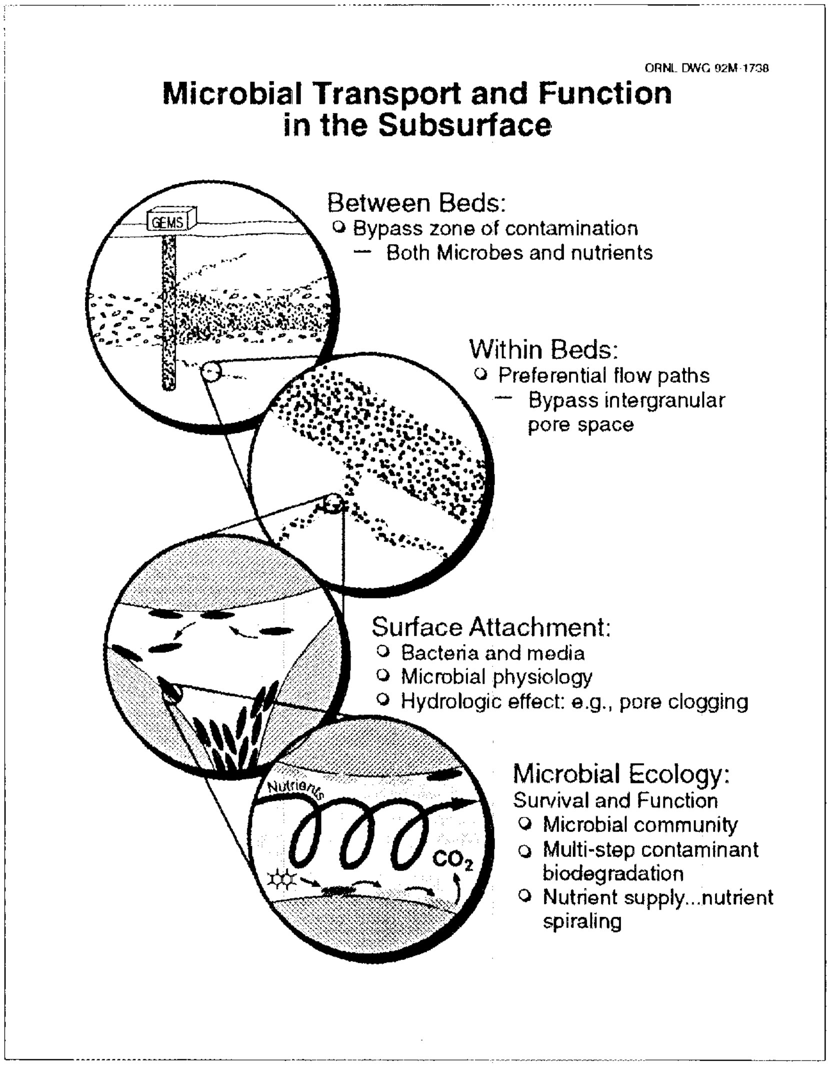


Figure 5.14 Physical heterogeneities in subsurface systems pose the same difficulties for the introduction of specialized or genetically engineered microorganisms to zones of contamination. Physiological and environmental factors influence the retention of bacteria within the aquifer.

Waste R&D—Basic Science • Although some of DOE's contaminated sites can be cleaned up with existing technologies, in many other cases our level of understanding of the complex systems associated with the remediation of past disposal sites and the transport behavior of contaminants is poorly developed. Foresight in identifying future needs as well as a relatively long-term commitment toward research directed at basic science issues related to environmental restoration are required; goals of this effort are laid out in terms of several decades rather than a few years. Leadership in this area of basic R&D must evolve rapidly and must integrate multidisciplinary science into a focused program that strives to develop the fundamental basis of knowledge that will be required to allow the DOE efforts at restoration to be successful in a cost-effective and environmentally safe fashion. Basic R&D support today will help ensure timely, cost-effective methodologies for tomorrow.

The basic R&D challenge is to address the following broad objectives that are representative of the foundation of a sophisticated understanding of long-term needs for environmental restoration:

- an understanding of the biological, physical, and chemical factors that control the movement and chemical transformations of radioactive, hazardous, and mixed wastes in subsurface and surface water systems;
- the development of methods for the accurate prediction of contaminant movement in the environment (Groundwater Transport in Environmental Modeling and

Remediation has been selected as one of two grand challenges in the High Performance Computing and Communications Program at ORNL);

- the development of new remediation technologies (i.e., physical, chemical, and biological) for environmental restoration;
- implementation of a consistent approach in assessing (1) the impact of remediation on human and environmental health and (2) the health and environmental risks associated with historic, current, and planned disposal operations; and
- utilization of methodologies in performance assessments and postremediation monitoring.

These broad objectives will demand a wide variety of technical disciplines as well as a highly interactive operational structure. For example, significant emphasis must be placed on developing (1) analysis capabilities including those related to geochemistry and hydrology as well as to risk analysis and (2) fundamental data bases that can support the analytical models. The interactive relationships between wastes of different types and natural processes of varying nature must be studied. Emphasis must be placed on microbial transformations that can be utilized in remediation as well as on other biological parameters that can effectively serve as risk and performance assessment evaluators. Inherent in this work will be the need for enhanced computational capability and the use of artificial intelligence and expert systems as means for aiding restoration decisions. The identification of basic research issues of importance to the waste R&D effort will change as technologies develop and as new problems are encountered.

KP03, KP04—Health Effects and General Life Sciences • Common themes within these activities are interactions of animals, cells, and molecules with their respective environments. In the analytical technology area, physical properties of materials of biological or environmental importance, mechanisms that govern transport and chemical transformations of pollutants, and the details of direct interactions of harmful agents with biological materials are studied through a variety of theoretical and experimental techniques. The efforts encompass interactions at the atomic, molecular, and macroscopic levels in solids, liquids, and gases; on surfaces; and at solid-liquid interfaces. Special emphasis given to interactions in liquids includes Monte Carlo modeling of radiation effects on biological molecules in irradiated matter. Strong emphasis is given to development of techniques that provide advanced instrumentation for characterizing and sensitively detecting a wide range of chemical species and related biomarkers of health effects. Included in this effort are unique applications of laser optical techniques, ultraviolet and soft X-ray spectroscopic techniques, electron-beam microlithography, electron microscopy, scanning tunneling microscopy, mass spectrometry, and picosecond laser techniques. ORNL's new program for experimental studies of picosecond processes in liquids, gases, and molecular clusters concentrates on studies of structure and dynamics relevant to energy deposition. Programmatic areas of emphasis include mammalian genetics, protein engineering, and cell biology.

Mammalian Genetics • Mammalian genetic research is utilizing existing mutational resources, as well as generating special new ones, for investigations into the DNA structure of certain genomic loci and regions, for correlating such structure with developmental processes, and for building bridges between the mouse and human genomes (Fig. 5.15). A recently initiated program in targeted mutagenesis is expected to add to the capabilities for functional analysis of genes.

Molecular and advanced cytogenetic techniques are used for analyzing the nature of agent-induced and insertional mutations—advancing the understanding of mechanisms of mutagenesis. The developmental pathology of selected mutants is investigated in depth, especially where such mutants provide models for human genetic disorders. In addition, the program is a national resource for studying genetic risk from environmental mutagens and for determining the sensitivities and biological properties of diverse types of reproductive cells.

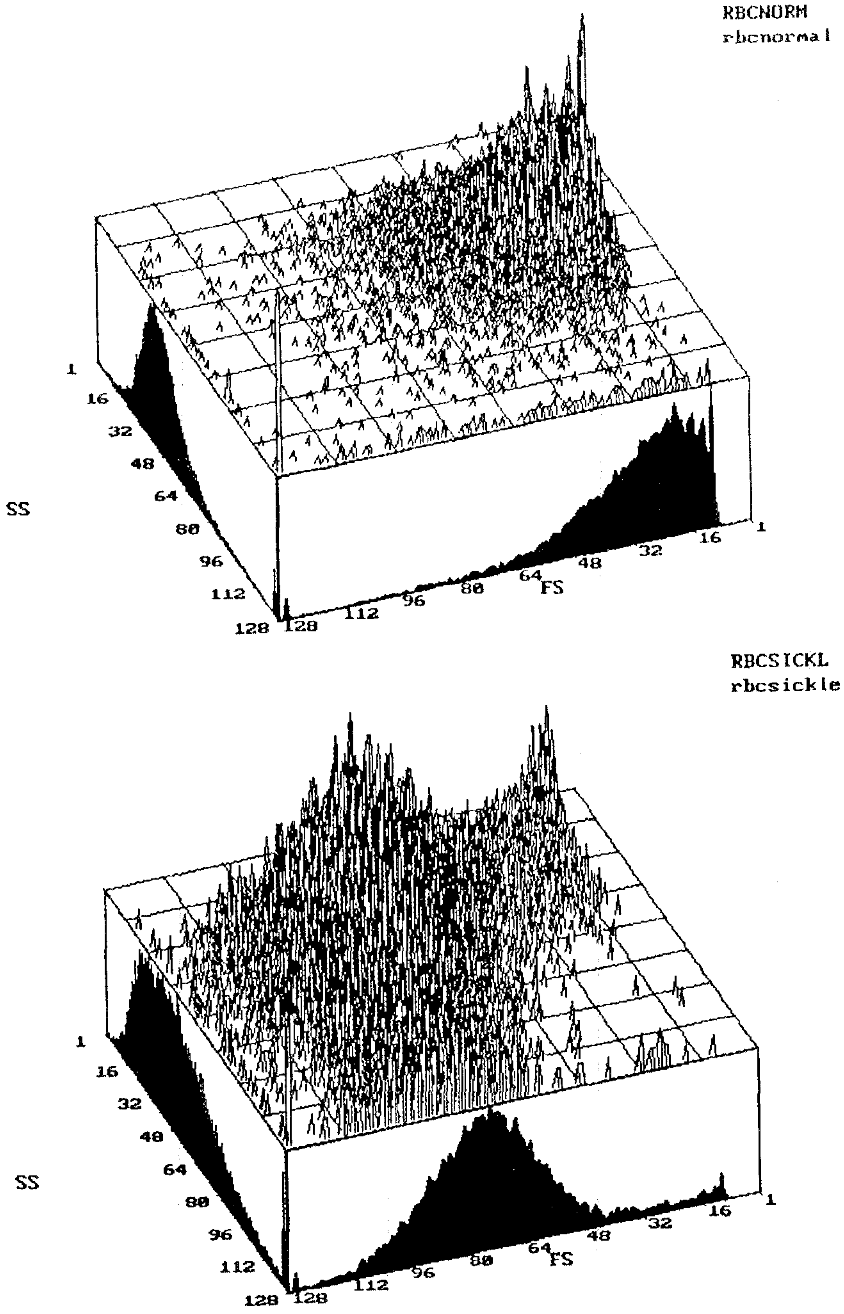


Figure 5.15 Cell-by-cell analysis of circulating red blood cells from normal mouse (above) and a mouse expressing the human gene for sickle cell anemia (below). The histograms show that the cells from the sickle-cell mouse are larger and more heterogeneous in their morphology. The introduction of the sickle-cell gene into the mouse strain was done by a combination of modern techniques of introducing DNA directly into embryonic cells and classical breeding techniques. The development of this strain at ORNL will be a major asset to research on sickle cell disease. (On the axes, FS=forward Scattering and SS=Side Scattering.)

Among recent accomplishments of the mammalian genetics program are the following:

- human DNA clones implicated in a pair of important human genetic diseases (Prader-Willi and Angelman) have been found to map within a genomic region of mouse Chromosome 7 that has been molecularly characterized in detail at ORNL, thus providing the opportunity to investigate basic mechanisms involved in these diseases;
- an insertional mutation has been generated and characterized that will provide an important animal model for human polycystic kidney disease (Fig. 5.16);

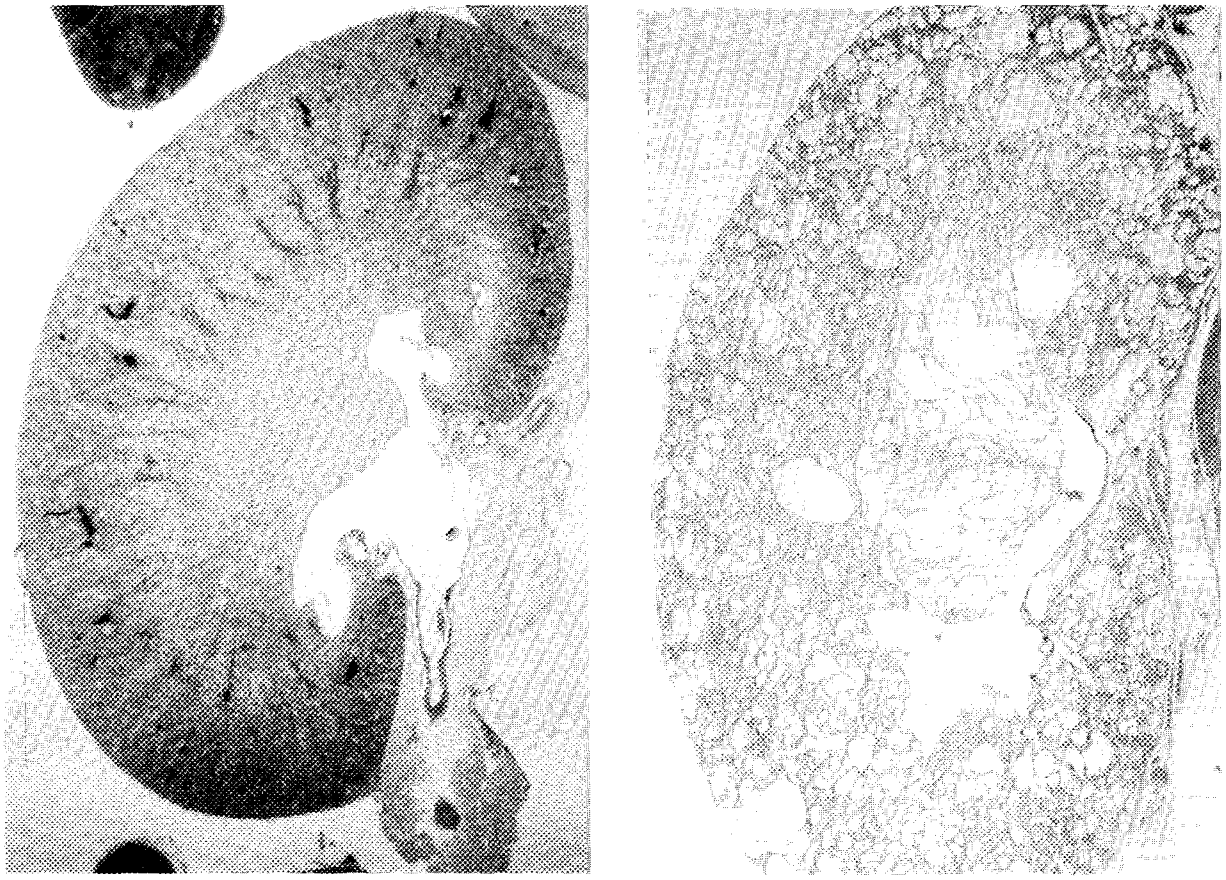


Figure 5.16
An insertional mutation induced by pronuclear injection of DNA has produced a valuable mouse model for one of the most serious genetic disorders in humans. The mutation Tg737 brings about polycystic kidney disease that in all details resembles a group of human conditions that currently affects 500,000 Americans. The section of normal kidney (left) shows a solid, homogenously stained structure; by contrast, the kidney from a mutant littermate (right) is seen to have large cysts and dilated ducts. The insertional mouse mutation is unique in that it has provided the first molecular handle on a gene that is associated with polycystic kidney disease.

- evidence has been obtained suggesting that interruption of the finely tuned program of very early gene expression in the conceptus could be the mechanism responsible for the high frequencies of congenital malformations that follow exposures of very early embryos to certain chemicals; and
- several chemicals have been found that are mutagenic only in females.

Closely aligned with mammalian studies, molecular genetics will include investigations of genomic structure, regulation of gene expression, and structure and function of gene products. Researchers at ORNL have the capability to visualize higher-order chromatin structure and the three-dimensional structure of nucleosomes (the core particle of chromatin) by using X-ray and neutron diffractometry and special techniques in electron microscope tomography developed at ORNL. Cloning of segments of the eukaryotic genome and their subsequent sequencing are providing new insights about the nature of regulatory elements of DNA and the propensity of small regions of DNA to undergo spontaneous mutations.

Protein Engineering • Protein engineering (site-directed mutagenesis) represents the use of recombinant DNA technology to alter the structure of proteins systematically by replacement, addition, or deletion of amino acids in targeted regions. In the scant 10 years since its inception, protein engineering has emerged as the most powerful tool for probing structure-function relationships and has opened exciting new vistas for optimizing properties of proteins for medical, industrial, and agricultural applications.

In terms of breadth and integration of many activities in molecular genetics and biochemistry, ORNL's program in protein engineering is unique among DOE laboratories. Current efforts center on several functionally diverse proteins: ribulose bisphosphate carboxylase/oxygenase (Rubisco), the CO_2-fixing enzyme and a determinant of biomass yield; EGF, a polypeptide hormone that stimulates cellular growth and differentiation; and O6-methylguanine-DNA methyltransferase (Ada), a protein that repairs mutagenic lesions in DNA caused by alkylating agents. With respect to Rubisco, there are two compelling reasons for carrying out site-directed mutagenesis: (1) despite the absolute dependence (direct for plant and indirect for animals) of all higher life forms on the enzyme, many mechanistic questions remain unanswered; and (2) if the enzyme's oxygenase activity (detrimental to net CO_2 fixation) could be reduced, major increases in plant productivity might be achieved.

Several extracellular protein factors are capable of stimulating the growth of cells and the expression of specific genes believed to be involved in the entrance of mammalian cells into, and progression through, the cell cycle. One of the most highly studied among these is EGF, a 6-kDa single polypeptide chain having three internal disulfide bonds that initiate its action through high-affinity ligand binding to the specific cell-surface EGF receptor. In response to EGF, the receptor undergoes autophosphorylation on tyrosine residues by its intrinsic protein kinase activity; this, in turn, phosphorylates exogenous substrates, which triggers a cascade of biochemical events, including increased glycolysis and protein synthesis and increased transcription of specific genes that ultimately lead to a stimulation of DNA replication and cell division. Some aspects of the function of EGF can be addressed by site-directed mutagenesis of the human gene that we have synthesized and cloned in *E. coli*.

The ubiquitous and unique Ada protein is responsible for the repair of O6-alkylguanine, a promutagenic and procarcinogenic lesion in DNA produced by many alkylating mutagens including N-alkylnitrosamines. This protein, in a suicide reaction, reacts stoichiometrically and irreversibly such that alkyl groups from DNA are transferred to cysteinyl sulfhydryl groups of the protein itself. The molecular basis for the multiple and disparate functions of the Ada protein are being studied by site-directed mutagenesis of both the structural and regulatory regions of its gene (already cloned and sequenced). Additional gene products under close scrutiny include enzymes involved in transcription of DNA and membrane-transport proteins responsive to environmental insults.

Recent accomplishments illustrating progress made in the protein-engineering program are as follows:

- The elucidation of the three-dimensional structure of Rubisco by Brändén and colleagues in Sweden validated our approaches to addressing structure-function issues by mutagenesis even in the absence of crystallographic data. These issues include identity of active-site residues, function of active-site residues, active-site location in oligomeric enzymes, and determinants of substrate specificity. Innovative chemical-rescue methods have been applied to questions of substrate specificity.
- Both agonists and antagonists of human EGF have been designed. The agonists may be super growth promoters having clinical application in wound healing; the antagonists offer potential as antitumor agents.
- By having cloned the DNA for human O6-methylguanine-DNA methyltransferase, the hypothesis that this repair protein (through gene amplification) is responsible for resistance of tumors to chemotherapeutic agents was verified.

Cell Biology • Several projects support or interface directly with those programs already described. The initiation events that convert normal cells to potential cancer cells are an essential stage in carcinogenesis but do not determine whether an overt cancer develops; host factors play a responsible role. Therefore, studies of the factors that influence whether an initiated cell progresses to a tumor or is suppressed in the expression of its cancerous potential, are central to the problem of carcinogenesis in general and radiation-induced cancer in particular. Thus studies continue on the mechanisms of cell-

cell interaction and the involvement of such factors as transforming growth factor β in control of neoplastic growth.

Various transgenic mouse lines, including those with interleukin-3 gene inserts, have been established for studying genetic factors associated with carcinogenesis influenced by environmental factors including radiations. A special emphasis in this program is placed on chemical carcinogens such as the commercial solvent tetrachloroethylene that appear to be negative in short-term tests for mutagenicity.

Cells destined for specific differentiated functions can frequently be studied to advantage in clonal lines in culture. Such cells initially proliferate and then cease growth when they differentiate. The requirements of the differentiated cells diverge from those of growing cells, and the changeover can be explored in the coordinated shifts in gene expression. Cultured kidney cells are providing a clear and illuminating model system of the genetic controls on glucose metabolism in the renal proximal tubule. EGF variants derived in the Protein Engineering Program are providing important insights to these regulatory mechanisms.

The cryopreservation of cells and embryos (the long-term goal is cryopreservation of multicellular organs) already has a very large and well-demonstrated value as an applied biological technique. Its further development depends on the continuing elucidation of the basic mechanisms in cell freezing; such studies are in progress. An important recent advance has been the recognition of the role of cell compression within ice channels formed during the freezing process.

Continuing Initiative

ORNL Genome Program

The Laboratory is strongly committed to an integrated effort to analyze the human genome. Study of the mouse genome and the development of advanced sequencing and mapping techniques are two principle thrusts of the ORNL program.

The analysis of the mouse genome and the interaction with studies on the human genome will proceed as follows:

- utilizing recently added capabilities for long-range DNA mapping, develop a molecular map for an entire mouse chromosome (Chromosome 7);
- map human cDNAs in Chromosome 7, and elsewhere in the mouse genome, to increase the information on human-mouse homologies;
- by means of our newly added capability in targeted mutagenesis, determine the function of some of the mapped human cDNAs;
- pursue intensive structure/function studies in genomic regions for which deletion complexes have been generated;
- study the feasibility of inducing deletion complexes throughout the genome;
- create molecularly tagged mutations throughout the murine genome by insertional mutagenesis, using both pronuclear-injection and embryonic-stem-cell techniques;
- use mutagenesis techniques of all sorts to create models of important human genetic disorders;
- establish a national data base for transgenic mouse mutants; and
- employ artificial intelligence and neural network techniques to identify important DNA sequence patterns.

New methods that will increase the rate and accuracy for sequencing and mapping, as well as unique informatics for pattern recognition in new sequence data, are being developed in parallel with the generation and molecular analysis of new germline mutations in the mouse. The major objective is to explore the structural and functional characteristics of the mammalian genome using experimental molecular genetics. Because many parallels exist between the human and mouse in anatomy and physiology, mutations in the mouse are powerful tools for analysis of the structure and function of the human genome.

New genome-mapping and sequencing technologies needed to provide rapid analyses for use in conjunction with analyses of the mammalian genomes fall into three categories:

- For conventional gel electrophoresis, methods are being developed to increase the rate of sequence analysis 10- to 100-fold by replacing radioisotopes with stable isotopes and the use of resonance ionization spectroscopy to detect DNA labeled with these isotopes. This employs state-of-the-art organometallic chemistry to synthesize the labels and new modification of resonance ionization spectroscopy to detect them.
- To eliminate the gel electrophoresis step, other methods are under development, some of which may increase the rate of sequence

analysis even further: one is sequencing by hybridization; others involve various mass spectroscopic methods of analyzing directly the DNA fragments that are usually subjected to electrophoresis (Fig. 5.17).

- By employing new detection techniques, sensitive and rapid DNA analysis can occur including single molecule detection of luminescence species; mass spectroscopic detection methods; and synchronous luminescence, phosphorescence, and enhanced Raman detection techniques.

Some of these procedures may also be adapted for genome mapping and for analysis of gel blots of DNA. The analysis of the mammalian genomes should be expedited when some of these techniques are available.

Unique computer-based sequence analysis methods for identification of biologically important regions in newly sequenced DNA are being developed based on neural network, artificial intelligence, and parallel computational techniques. An expert system is under construction for rapid and reliable localization of gene components such as exons, introns, and gene control elements and the automated assembly of these components to describe whole genes. Not only is a portion of this system being used currently at ORNL to localize genes in mouse studies, but more than 200 other laboratories have submitted sequence data to be searched for important human disease genes.

Biological imaging, which involves the use of a novel class of microscopes, has been identified as a cost-effective, high-volume technique for studying DNA. These microscopes work by scanning a tiny probe very near a surface onto which DNA molecules have been applied; they have the potential for performing genome mapping and sequencing functions.

The Human Genome Management Information System was placed at ORNL to provide the DOE and National Institutes of Health (NIH) human genome programs with a communication network throughout the international community that is engaged in human genome research. The *Human Genome News* and the *DOE Human Genome Program Report* are published at regular intervals from this office.

Found throughout the Laboratory and in local industry, facilities that support these main components include

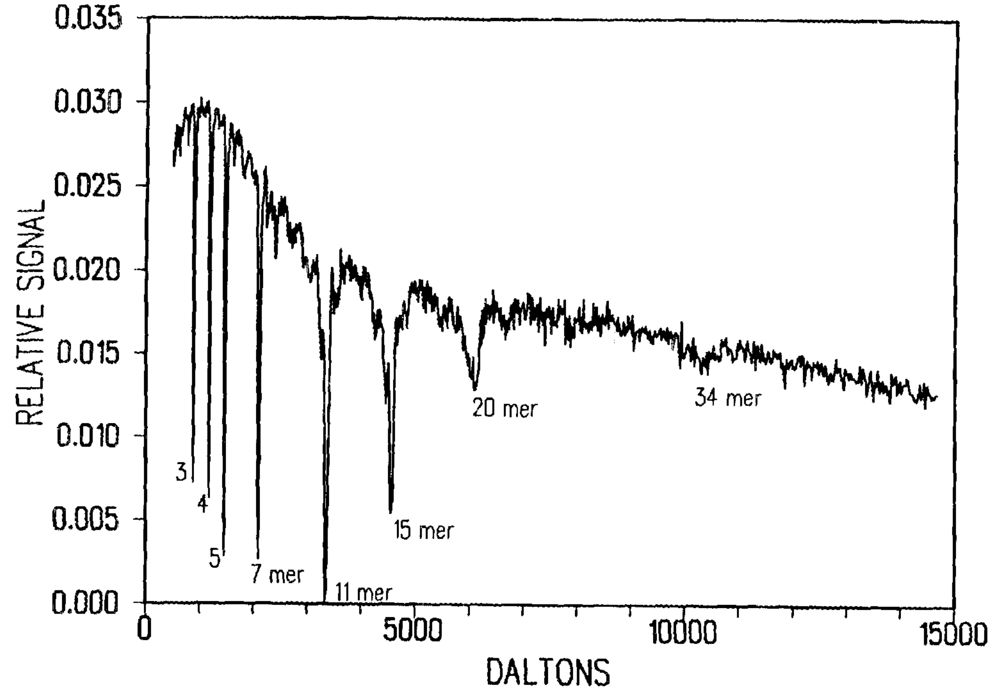


Figure 5.17 The Photophysics Group in HASRD is developing laser desorption mass spectrometry in support of DOE's Human Genome Program. This figure represents the successful detection of oligomers containing up to 34 base pairs (a current record).

- a 250,000-mouse colony organized for genetic studies;
- a transgenic mouse facility;
- an NIH-supported database for transgenic mice;
- the ORNL Advanced Computing Laboratory;
- resonance ionization spectrometry laboratories;
- synthetic chemistry laboratories;
- a laboratory equipped with two DNA synthesizers;
- high-resolution mass spectrometry laboratories;
- analytical chemistry facilities that include high-resolution FT-MS, FT-NMR, FT-IR, and ultra sensitive laser luminescence capability;
- facilities for sensitive detection of labeled DNA fragments by mass spectrometry;
- facilities for sensitive detection by enhanced Raman, luminescence, and phosphorescence; and

- a cryobiology facility to preserve embryos that contain valuable mouse mutations.

A number of divisions of the Laboratory are currently interacting to develop this multifaceted program, including Biology, Chemistry, Analytical Chemistry, Health and Safety Research, Instrumentation and Controls, and Engineering Physics and Mathematics. Table 5.11 lists the budget projections.

Table 5.11
Budget projections by fiscal year for Genome Mapping and Sequencing[a]
($ in millions—BA)

	1993	1994	1995	1996	1997	1998
Operating expense	4.2	6.5	6.8	7.1	7.4	7.7
Capital equipment	0.4	0.3	0	0	0	0

[a]Funding is being sought from the Office of Energy Research under Program KP, Biological and Environmental Research.

KP05—Carbon Dioxide Research • In the area of global environmental concerns, ORNL has become a center of expertise in developing global biogeochemical models, implementing data and information systems, fostering the application of high-performance computing to atmospheric general circulation models, conducting field and laboratory research on CO_2 effects on vegetation, and developing unique instrumentation packages for global applications. These activities are the foundation for the ORNL Center for Global Environmental Studies. This Laboratory-wide program involves staff members from many ORNL divisions as well as outside collaborators.

Resource Analysis • As part of the Resource Analysis Initiative, ORNL's ESD is supporting the studies that DOE's Carbon Dioxide Research Program is conducting on the effects of increasing CO_2 and changing climate on natural and societal resources. Measures that society might take in response to those effects are also being examined. The major tasks managed by ESD include assembling and ensuring the quality of data bases used in these studies, evaluating the potential effects of CO_2, climate change, and rising sea level on environmental resources, and developing methodologies for using climate model output in effects studies.

Global Carbon Cycle • The main objective of the Global Carbon Cycle Research Program is to develop a scientific basis for predicting changes in atmospheric CO_2 concentrations in response to continued releases of CO_2 by fossil-fuel combustion. Future activities will encompass more research that focuses on terrestrial and oceanic carbon dynamics, global carbon-cycle modeling, and the potential for positive feedback to alter our current understanding of the carbon cycle dramatically. Research will be concentrated on multidimensional models of the global carbon cycle; this will yield various estimates of atmospheric CO_2 when given different levels of fossil-fuel use and other variables relating to biogeochemical dynamics. Integration of the research with other collaborators is necessary to develop the information and models needed to provide accurate projections of CO_2 buildup in the atmosphere (from both natural and human sources) during the next century.

Carbon Dioxide Information Analysis Center • The objective of CDIAC is compilation, evaluation, and distribution of CO_2-related information in support of the program. In the coming years the center's research activities will reflect the new directions of the program. The center's activities will include research in all aspects of the CO_2 issue.

Computer Hardware, Advanced Mathematics, and Model Physics • The objective of the CHAMMP Program is to develop an advanced climate model that utilizes the hardware and software capabilities of massively parallel computers and incorporates the best numerical approaches for atmospheric and oceanic dynamics, together with the most accurate representation of cloud feedbacks, chemical processes, and terrestrial systems. In the near term CHAMMP will achieve improved general circulation model performance by taking advantage of parallel super computers such as those that are available in the Center for Computational Science. ORNL scientists are working in collaboration with staff members from ANL and NCAR to provide parallel implementations of the community climate model and to improve key numerical algorithms for parallel computation. ORNL scientists are keenly interested in the CHAMMP projects that will couple atmospheric, oceanic, and terrestrial models together. With these models new understanding of the CO_2 problem may be gained.

Carbon Dioxide Effects • The responses of temperate forests to enrichment of the atmosphere with CO_2 are unknown. Supporting DOE Direct Effects research, ORNL scientists have shown that growth of tree seedlings increases as the CO_2 concentration rises, but the testing of hypotheses about the long-term responses of forest ecosystems to CO_2 enrichment requires longer-term experiments with a focus on physiological and ecological processes. Future research will improve knowledge of critical mechanisms governing ecosystem responses to atmospheric CO_2; this will lead to a more realistic assessment of the role of terrestrial CO_2 responses in global carbon cycle research than is currently available.

Atmospheric Radiation Measurement • The objective of the ARM Program is to provide an experimental test-bed for studying important atmospheric effects, particularly cloud and radiative processes, and for testing parameterizations of these processes for use in atmospheric models. ESD staff are assisting DOE in the development of the ARM Data Archive at ORNL, capable of handling the massive amounts of data anticipated over the 10 year lifetime of the program; the first ARM field site was occupied in the summer of 1992.

Continuing Initiative

Center for Global Environmental Studies

Many of the decisions that will determine our direction in the next millennium hinge on issues that are complex, interwoven, and global in scale: greenhouse gases, climate change, ozone breakdown, deforestation and desertification, resource depletion, and the spread of pollution. These and other global environmental issues must now be explored far more seriously—far more comprehensively—than ever before.

ORNL's Center for Global Environmental Studies, established in 1989, provides a unique, interdisciplinary base for such explorations. The center has three main goals:

- improving the understanding of the global-scale workings of environments in air, on land, and in water;
- developing capabilities to anticipate the long-term, large-scale effects that human actions have on the biosphere; and
- identifying appropriate options for technological and societal responses.

In March 1992, the Center for Global Environmental Studies was elevated to a Laboratory-wide program, which recognizes ORNL's continuing interest in and commitment to understanding of environmental issues.

Like the U.S. Global Research Program, the crosscutting national initiative to which the ORNL center corresponds, the Center for Global Environmental Studies takes a new view of the kinds of research needed in this formidable but exciting field. The center's work is based on the unique capabilities of ORNL that set it apart from traditional institutional approaches to large-scale research and analyses. Our approach to these global issues is threefold:

- The scope of the processes and problems we are exploring is far greater—both in scale and in time—than traditional research projects are equipped to handle. Problems such as ozone depletion, the greenhouse effect, and global change are no respecters of national borders: they affect the entire planetary commons. Our understandings and responses, therefore, must be equally broad. Similarly, processes such as climate change and dwindling biodiversity may become clearly evident only when viewed over decades or even centuries. We must, therefore, envision and develop programs that can serve as foundations on which to build for many years.

- Collaboration—both among traditionally competitive institutions and across disciplinary boundary lines—is absolutely essential for any meaningful understandings to emerge. The globe's environment responds to the interactions of many different systems, factors, and processes: air circulation, ocean currents, land-use changes, economic incentives for development (or its converse), the migrations of smokestack industries, national energy practices and policies, and even political turmoil. Narrow, discipline-bound approaches can give us only detailed analyses of individual aspects of the biosphere (individual trees). But what we need now is an overarching view of the global environmental forest.
- Policy—economically and politically practical policy—must be one of the prime drivers of global environmental research. We must consider not only what is happening in (and to) the biosphere, and not merely what should (ideally) be done about it, but also what can be done—given the economic, technological, and political constraints within which actions must be taken.

These, then, are the principles that guide the center's organization and work: a large-scale, long-term view; a commitment to collaboration both among institutions and among disciplines; and a continual eye to realistic policy.

Areas of Focus • In keeping with the center's large-scale view, the central and unifying framework for our work is global systems analysis: developing increasingly sophisticated models that reflect the dynamic interactions of numerous subsystems—global vegetation; human cultures and behaviors; and earth systems such as atmospheric chemistry, ocean composition and circulation, and the links between air, land, and sea. Our long-term goal is to develop models that reflect the interplay of demographics, land-use patterns, economics, ecological relationships, and other factors that influence the globe's environment.

Complementing our central focus on global systems, four areas of more specific concentration are

- Measurement science and instrumentation—better monitoring of the state of the environment and its changes. ORNL has a long history of excellence in instrumentation in high-energy physics, health physics, pollution monitoring, nuclear reactor technology, and nuclear and chemical waste. We are now directing this expertise toward instrumentation for atmospheric, terrestrial, and aquatic research. Areas of strength that can immediately benefit the center include laser-based instrumentation (expected to play an increasingly vital role in global-change research); mass spectrometry and isotopic analysis; remote sensing and fiber optics, key technologies for climate studies; and automation, miniaturization, and portability. Logical applications of this expertise include laser-based devices to measure trace gases, temperature, and pressure; low-cost, air-dropped packages for reading atmospheric or ocean conditions; and instruments for studying cloud formation and atmospheric properties in support of the ARM Program.
- Data systems—the key to making sense of the global environment, now and for decades to come. The amount of data collected in the course of global environmental research is already staggering, and it will grow explosively as newer, more sophisticated instruments and monitoring projects emerge. For example, in a few years NASA's Earth-Observing System will begin transmitting enough data to fill all the books in the Library of Congress—every three weeks. In addition to handling massive quantities of data, information systems must present the data in a user-friendly form, one that will also ensure the usability of information over decades because the import of some data may not become clear for many years.
- Large-scale environmental studies—projects that examine the environment from a longer perspective than traditional ecological research. Global-scale studies cannot be based on mere extrapolations of traditional detailed studies; many of the subtle ecological processes on which traditional research thrives are less meaningful for these purposes than aggregate processes that are invisible at close range. The ORNL center is developing tools and techniques for understanding how to scale up research to the global scale that is now needed.
- Policy, energy, and human-systems analysis—the recognition that humankind

is inextricably linked with the physical systems of the earth. In the past two centuries our species has emerged as a major—perhaps the primary—agent of global environmental change. Therefore, questions of human activity and policy (including the effects of technology, energy conversion, land use, population growth, and political and cultural patterns) must play a key role in global environmental studies. The Center for Global Environmental Studies is bringing together anthropologists, economists, political scientists, sociologists, planners, geographers, climatologists, and ecologists to examine the decision processes involved in global management of risks and resources. Building on extensive work already under way at ORNL and elsewhere, we are developing the theoretical underpinnings of a practical approach to the problems of decision making involving many players and complex technical issues. Ultimately, this approach will produce a blend of theory and practice that erases the line that for so long has separated the "thinkers" from the "doers." The policy issue work is supported through PE and is coordinated by that office. Over the past several fiscal years KP05 funds have supported research and assessments in resource analysis (see discussion of KP05—Carbon Dioxide Research) to translate the results from global carbon models and atmospheric circulation models into meaningful results for policy analysis. This work has experienced declining budgets and will essentially be phased out in FY 1992. At present, there is no WFO funding for policy assessments of global climate change.

Key Projects and Goals • A brief sampling of current and planned work by the Center for Global Environmental Studies will help convey the breadth of its research and vision.

Current Research

- Development of integrated land-use models. Our studies of tropical deforestation in Brazil, sub-Saharan Africa, and Southeast Asia are contributing to the development of models that integrate the socioeconomic and biophysical aspects of land-use change. For example, because most of the Brazilian deforestation results from road building and agricultural clearing, the problem and its solution involve nearly every element in the global-change picture: land use, politics, environmental systems, and socioeconomic activity. For this reason, our work involves close interdisciplinary collaboration among experts in geography, ecology, transportation, economics, and other fields.
- Refined modeling of the global carbon cycle. Carbon dioxide is the greatest single contributor to the greenhouse effect; therefore, a clearer picture of the sources, sinks, and fluxes of carbon throughout the globe is essential in facing the greenhouse effect and the climate changes it may bring. ORNL's Global Carbon Cycle Modeling Group has developed, and has access to, many carbon-cycle models. After exercising these existing models rigorously, we are now beginning to develop new models that reflect various "feedbacks" within the carbon cycle and are bringing a unifying theme to the development of fully integrated carbon-cycle models.
- Information analysis centers. One goal of this initiative is to create massive data bases on worldwide climate. These data bases would allow us to determine whether global warming has actually occurred. Our selection as the ARM user facility and data archive will provide a sound basis to begin this research. Development of other areas such as biomass data and human-systems data will solidify our role in this arena. Another goal is the development of visualization systems for data-intensive studies. ORNL's CDIAC is a powerful data-management center with proven expertise in global environmental studies; it represents a valuable "head start" in our new center's data-systems initiative. We are also collaborating in an initiative to establish a Center for Human Dimensions and Global Change Data.
- CHAMMP Initiative. Atmospheric-circulation models pose some of the most complex, computer-intensive problems in scientific research today. ORNL computer scientists and mathematicians are harnessing the world's fastest parallel computers for this challenge. With these computers it will be possible to simulate more complex interactions with more detail than previous models and to give a broader and more comprehensive view of our earth system.
- International development and global environment. The impacts of both climate change and climate-change policies will fall heavily on developing countries. At present, our work in this area includes identifying vulnerable regions; determining the effects of existing aid programs on global

environmental change; analyzing the impacts of change on current development plans; and finding new opportunities to enhance development and, at the same time, pursue environmental goals. Energy efficiency, institution building, and technology transfer for developing countries are high priorities for this ORNL activity.

- Improved radiation-measurement instruments for the ARM Program. Drawing on ORNL's proven expertise, we are developing advanced new instrumentation that will provide better data on global radiation and heat fluxes—data that will allow development of more accurate atmospheric models.
- UV-B research agenda. Because much of ozone depletion is due to various energy technologies, and because other adverse effects of fossil fuel derived pollutants may be amplified by ultraviolet light, the suggested change in UV-B radiation is clearly linked to the development of a national energy strategy. We believe that a comprehensive analysis of the technical issues associated with UV-B radiation will help resolve many of the uncertainties dealing with measurement sciences and instrumentation needs and will bring a focus to the full spectrum of issues surrounding UV-B measurements and the effects of potential UV-B increases on biological systems. Through a Critical Issues Workshop, we will begin to develop a comprehensive research agenda for resolving these issues.
- Policy-driven impact analysis. We are in the first stages of developing an integrated approach to analyzing impacts of global environmental change. Current approaches are generally restricted to projecting short-term changes in resources (such as surface water on coastlines) onto current socioeconomic and geographical conditions. The results of such projections are of very limited use to policymakers. Our alternative approach will be an interdisciplinary analysis, one whose starting point will be the real-world problems policymakers face in a given region and time; the analysis will allow for technological and demographic changes and will indicate how significantly climate-change impacts would affect decisions. Our ultimate aim is to devise personal computer–based decision-support systems for federal, state, and local decision makers.
- A global vegetation model. Building on our current study of the global carbon cycle, we plan to extend the vegetation model to encompass the entire globe. The expanded effort (estimated to take 10 to 20 years) will represent a major new contribution to global modeling.
- Development of improved data-storage techniques. As the ARM Program and other data-intensive programs mature, new ways of archiving and accessing information will be needed—ways that preserve the usefulness of prior data while anticipating even greater future data-handling needs. Our strength in information analysis and management, together with ORNL's growing expertise in scientific computing, gives us a solid basis for developing better data-storage techniques and systems.
- Predictive models for water resources. Water resource problems will surface as a dominant global issue if the effects of global change begin to manifest themselves. While problems in the developed nations will be severe, water-related issues in developing countries will have significant economic and environmental ramifications , especially as the effects influence energy-related activities. Using large scale assessment techniques and tools developed for assessment of global effects on other resources, we are developing a major new initiative in water resources directed towards the needs of developing countries. Our approach will be to develop predictive models that will help decision makers understand freshwater ecology, hydrology, and water resource management in the context of global change.

Summary • The range and depth of ORNL's scientific expertise uniquely qualify the Laboratory to take up the challenges of the Global Change Program. By establishing the Center for Global Environmental Studies, ORNL is drawing on its proven expertise and worldwide scientific connections while also laying the foundation for expanded, focused research into the problems of global change.

The Center for Global Environmental Studies is dedicated to an earth system–centered, interdisciplinary approach to scientific research. It views human interaction with the environment—through population distribution, land use, technology, energy conversion, and other processes—as one of the driving forces of global environmental change. The center stands in a unique position to serve the needs of federal agencies and international efforts and to make a significant contribution to our understanding of the delicately balanced biosphere we call home. Table 5.12 lists budget projections.

Table 5.12

Budget projections[a] by fiscal year for the Center for Global Environmental Studies[b]

($ in millions—BA)

	1993	1994	1995	1996	1997	1998
Operating expense	15	17	18	18	18	18
Capital equipment	2.0	3.0	1.0	0.5	0.5	0.5

[a]Projections include university subcontracts. About 80% of funding would come from DOE; the remaining 20% from non-DOE funding.

[b]Funding is being sought from the Office of Energy Research under Program KP, Biological and Environmental Research.

KP06—Medical Applications

Nuclear Medicine • Research conducted in the Nuclear Medicine Program continues to receive international recognition and focuses on the design and development of new, improved tissue-specific radiopharmaceuticals for diagnosis and therapy (Fig. 5.18). Agents developed in this program are being studied for both preclinical and clinical evaluation with more than 20 medical cooperative programs at university hospitals and in research institutions in the United States and abroad.

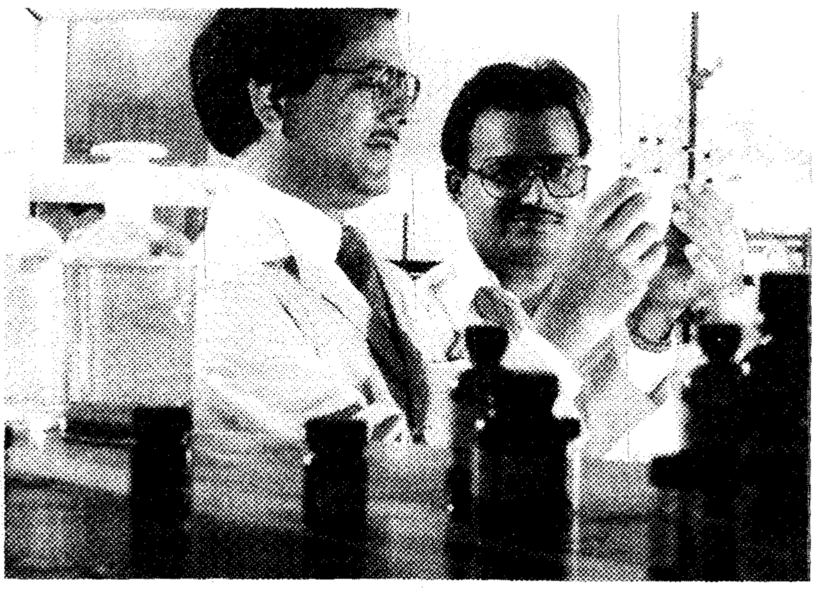


Figure 5.18
P. C. Srivastava (left), staff scientist in HASRD, and Ahmad Hasan, postdoctoral research associate, discuss molecular design of a radiopharmaceutical for improved diagnosis and therapy of cancer.

Current tissue-specific radiopharmaceutical research includes radioiodinated receptor-specific antagonists that bind to cerebral receptors involved in neurotransmission. The goal is to measure by external imaging techniques changes in receptor density or activity that occur in many diseases. Agents under development include new, improved analogues that bind to the cholinergic-muscarinic receptors and the synthesis of new analogues for binding to the serotonergic receptors that are involved in mood disorders. In conjunction with these and other agents, new, improved radiolabeling techniques are being developed for introduction of radioiodine into molecules sensitive to the usual methods of radioiodination. Recently, a new radioiodinated agent has been developed for the evaluation of gastrointestinal disorders involving pancreatic disease by a simple urine test. Clinical studies have been initiated with this agent, and the results of initial testing in normal volunteers look very promising.

The ORNL HFIR is an important resource for the preparation of high-specific-activity radionuclides required for radiopharmaceutical research and as parents for the development of radionuclide generator systems being developed in this program. The development of radionuclide-processing technology and generator research continue to be major areas of productive research. The first large-scale clinical prototypes of the tungsten-188/rhenium-188 generator developed in this program have been prepared, their performance has been evaluated, and they have been successfully used to radiolabel antibodies that show tumor specificity in animal studies. Approval has been obtained for the initiation of the first patient studies in conjunction with the Center for Molecular Medicine and Immunology in Newark, New Jersey. Another new generator developed is the osmium-194/iridium-194 system to provide the iridium-194 for therapeutic applications.

Another area of research involves the development of various new therapeutic agents, including modified nucleosides for the potential diagnosis and therapy of tumors. A variety of new analogues have been synthesized and are currently in various stages of animal and in vitro testing. New radiolabeled maleimide agents, which bind to antibodies and other proteins by reaction with free sulfhydryl groups, are also being developed and tested.

In addition to these successful areas of research, a variety of invention disclosures, patents, and licenses have been consummated. The medical cooperative programs represent an effective mechanism for further evaluation of agents developed in this program through collaboration with programs featuring special expertise in cardiology, oncology, and other areas.

Molecular Immunology • The proteins on the surface of cells are tissue-specific and may be altered in kind and amount in the carcinogenic process. Monoclonal antibodies have been developed that recognize epitopes on a glycoprotein (thrombomodulin), which is expressed exclusively by lung endothelial cells. This apparently unique glycoprotein provides opportunities for the use of the monoclonal antibodies for imaging both the vasculature and tumors. Liposomes can be targeted with these monoclonal antibodies with the possibility of targeting chemotherapeutic agents. The potential for these applications will be exploited in the light of basic studies of the surface proteins in normal and cancer cells.

KS—Superconducting Super Collider

Research in support of the SSC is being performed on nuclear collision models and detector physics performance, mechanical engineering, and electrical engineering. Work in support of the SSC is expected to increase rapidly. (See the section on the Oak Ridge Detector Center and the High-Energy Physics Program.)

KT—University and Science Education and KV—University and Science Education–Defense-Related

The ORNL-obligated portion of the KT and KV programs supports the administration and conduct of both university-level and precollege mathematics and science education activities. University programs include DOE's Science and Engineering Research Semester (SERS), the Great Lakes Colleges Association/Associated Colleges of the Midwest Science Semester, and a range of other student-faculty research participation and internship appointments, including visits to ORNL by minority educational institution (MEI) faculty. The KT and KV programs, designed to encourage college and university faculty and student involvement in DOE missions, provided opportunities for more than 500 academic participants at ORNL during FY 1992.

In the area of precollege science education, the KT and KV programs help support

- ORNL's core precollege program, the Ecological and Physical Sciences Study Center, which offers some 40 different half-day study units for class-size groups and last year served 24,000 East Tennessee students from kindergarten through 12th grade;

- initiatives with UT to establish the Academy for Teachers of Science and Mathematics and to provide an alternative path for degreed professionals in technical disciplines to prepare for teaching careers;
- administration of DOE's national Teacher Research Associates Program, which provides full-summer appointments at ORNL for more than 50 secondary teachers annually;
- a regional mathematics and science camp to encourage young women of middle-school-age to pursue further studies in these fields; and
- two special summer programs that provide intensive 2-week hands-on learning experiences under the direction of ORNL technical staff members—the DOE High School Honors Workshop in Environmental Sciences and the Appalachian Regional Commission Summer Science Honors Academy for student-teacher teams.

Continuing Initiative

Education Technology

The particulars continue to be debated, but on the subject of American education, U.S. citizens and their leaders agree on two points: the precollege system is in decline, and dramatic measures are essential if the nation is to retain its position as a world power. The indicators of weakness are discouragingly familiar: low test scores in comparison with our international competitors, an industrial work force that increasingly requires remedial education, and—among countless others—high school dropout rates that exceed 50% among certain minority populations. Alarmed by these danger signals, the president and all 50 governors have established a single platform on which to rebuild the U.S. education system by the year 2000. Teacher groups are developing national standards for curriculum, teaching, and assessment. In the vital fields of science and mathematics, ORNL works with various universities, school systems, and federal agencies to provide innovative programs for some 24 thousand precollege students and teachers every year.

As the debate escalates and as more and more issues work their way onto the reform agenda, one key factor remains largely overlooked: the American classroom has not kept pace with the technological transformation of our society. The explosion in computer technology, in particular, has fundamentally altered the American workplace. Virtually no business or industry remains untouched. Yet computers continue to play a minor, supplementary role in a passive educational process that relies almost entirely on books and lectures for the transfer of knowledge.

Since the Industrial Revolution, mass education has required dependence on indirect experience—direct experience abstracted into books or other static media. Frustrating even for many of the brightest students, this approach has finally been pushed beyond its capabilities. Today there are alternatives. The technology of the Information Age offers unprecedented opportunities for stimulating the learning process. High-performance computers, together with high-speed computer networks, can deliver interactive images, text, and other enriching material from a limitless number of remote locations. They also are capable of creating and mass distributing "virtual realities" that participants can see, feel, and interact with in an astoundingly lifelike emulation of direct experience.

The Educational Technology Initiative is a bold plan to revolutionize education in the United States by exploiting this computer technology. It encompasses both short-term objectives that employ current technology and long-term objectives that will harness emerging technologies for the classroom of tomorrow. Short-term projects were selected on the basis of their potential for establishing a foundation for the long-term objectives as well as for their inherent value as learning tools. Examples include

- the Oak Ridge Educational Network (OREN) funded by DOE to develop and demonstrate a model for internet connectivity for kindergarten through grade 12 along with software development and analysis to enable teachers and students to locate and use the internet more effectively and at low cost;
- the on-line Smithsonian, a partnership for exploring methods of storing and accessing information on one or two broad topics such as native American history or dinosaurs;
- Demonstration Virtual Reality Teaching Units, portable means for experiencing geography and history; and

- regional workshops, involving teachers and school administrators in the development of these products for the school systems.

While the long-term objectives will require extensive R&D of hardware, software, and learning paradigms, several ideas are on the drawing board. Examples include

- the Information Store (providing access to computer-based resources);
- furnishing virtual reality capability to the kindergarten through grade 12 classrooms; and
- a holographic animation as a teacher's assistant or mentor.

The Education Technology Initiative will be developed, implemented, and financed through a consortium headed by ORNL that includes UTK, Vanderbilt University, Tennessee State University, the Tennessee State Department of Education, the Tennessee Valley Authority (TVA), and several industrial partners. A steering committee selected from these organizations will provide management oversight. The work will be performed by

- **The Center for Educational Technology Innovation** This center will be housed with the Center for Computational Science being formed at ORNL and will share its facilities and resources. Support staff will be drawn from within ORNL and other parts of Energy Systems as well as from other partners in the initiative. An early task will be the installation of prototypic high-performance computers and a very high speed network for evaluating virtual reality traffic, interactive video, and data-base traffic to schools selected as initial program targets.
- **The Education Technology Institute (ETI).** Coordinated by the ORNL Office of Science Education and External Relations (SEER), ETI will be a joint venture initially involving UT, Vanderbilt University, and Tennessee State University to explore the best ways to use this technology to promote learning. It will focus on curriculum development, training to use the technology, research into learning and presentation methods using advanced technology, and the development and staffing of regional training programs for deploying the technology.
- **The Classroom Experimental Projects Office** This office, corrdinated by SEER, will work in conjunction with school systems through the Tennessee State Department of Education to provide training materials, release time for training, and in-service institutes focusing on using the technology and curricula in the classroom. It will be responsible for selecting target and control test schools and implementing the test curricula in those institutions. The Tennessee State Department of Education will provide the major support—assisting with the administrative and logistical details of actually using the new materials in classrooms.
- **The Tennessee Valley Authority/Private Sector.** Experienced in planning, demonstrating, and evaluating educational technologies, TVA will provide technical assistance in hardware, software, school system, and statewide interfacing. A number of telecommunications and computer companies have also expressed interest in providing financial and research assistance.

Targeted at kindergarten through grade 8, this initiative is designed to serve as a catalyst for stimulating change in schools nationwide. Unique in approach and scope, it blends high-performance computers, high-speed networks, and high-technology advances such as virtual reality. It draws strength from a partnership involving government, industry, and higher education. And perhaps most important, it emphasizes learning through direct, interactive experience—possible on a large scale for the first time since before the Industrial Revolution.

If the United States is to fulfill its aspirations for education, we must work fast to extend the technology of the Information Age beyond the nation's offices and factories and into the classroom. If we seize the initiative now, the infrastructure will be in place in time to take full advantage of next-generation technologies as they emerge (Table 5.13).

Table 5.13

Budget projections by fiscal year for the Educational Technology Initiative[a]

($ in millions—BA)

	1993	1994	1995	1996	1997	1998
Operating expense	5.0	6.0	7.0	7.2	7.4	7.5
Capital equipment[b]	4.0	4.0	3.0	2.0	2.0	2.0

[a]Funding is being sought from the Office of Energy Research under Program KT, University and Science Education.
[b]Corporate partner capital donations could reduce the capital requirements substantially. In addition, a conservative estimate has been made of the amount of capital required to provide networked individual virtual reality experience in the kindergarten through grade 12 classrooms for this prototype.

ORNL will continue its strong focus on programs that increase opportunities in science, engineering, and mathematics for underrepresented groups, including women, minorities, and people with disabilities. Interactions with historically black and other minority institutions are carried out under a formal DOE/ORNL memorandum of understanding with the University of Puerto Rico; through the Science and Technology Alliance, a historic partnership that joins ORNL and two other national laboratories (Los Alamos and Sandia) with three minority institutions (the Ana G. Méndez University System in Puerto Rico, New Mexico Highlands University, and North Carolina A&T State University); and with other university and industry associates, the latter including Martin Marietta Corporation, through joint efforts with the 17-member DOE-sponsored historically black colleges and universities/minority educational institutions Environmental Restoration and Waste Management Consortium; and under programs with individual institutions and researchers. In addition, formal DOE and/or ORNL memoranda of understanding are in place with three minority universities—Clark Atlanta, Southern, and Tuskegee—with Wesleyan College in Macon, Georgia, the world's first institution chartered to grant baccalaureate degrees for women, and with the National Autonomous University of Mexico.

KU—Laboratory Technology Transfer

The KU program has been established to help bridge the gap between R&D and commercialization through CRADAs. A CRADA is a joint R&D mechanism that allows ORNL to enter into cost-sharing arrangements with industry to allow joint research among the working-level scientists and engineers.

Assistant Secretary for Nuclear Energy

The Assistant Secretary for Nuclear Energy is the major sponsor of applied nuclear at ORNL (Table 5.14). Programs funded through this office are multidisciplinary and include nuclear energy R&D, naval reactors, isotope production and distribution, nuclear safety, new production reactors, and defense programs.

Table 5.14

Assistant Secretary for Nuclear Energy major program summary

($ in millions—BA)[a]

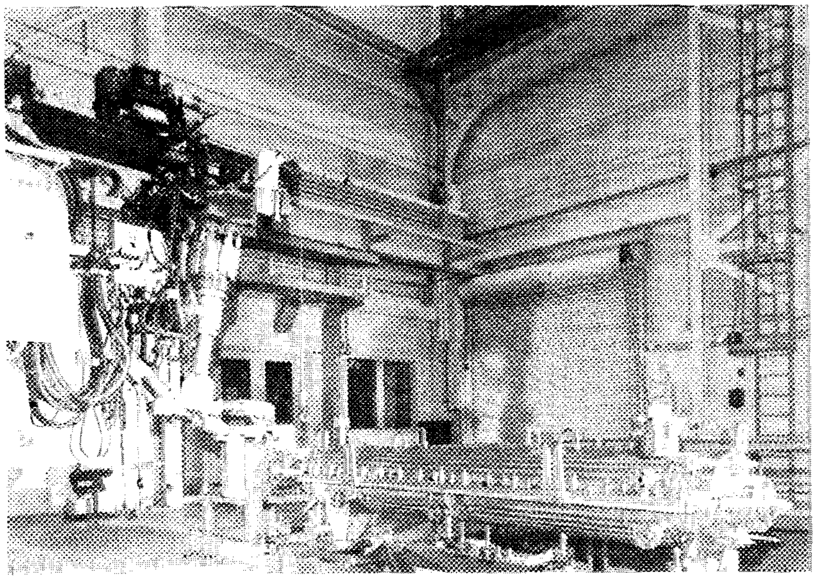
Budget and reporting code	Major program	FISCAL YEAR 1991	1992	1993	1994
AF	Nuclear Energy R&D	32.8	24.6	51.1	50.2
AJ	Naval Reactors	0	0.1	0.1	0.1
CD	Uranium Enrichment	0.6	0.5	0.5	0.5
KK	Policy and Management—Nuclear Energy	2.9	2.2	3.1	3.1
ST	Isotopes	3.0	7.9	14.0	14.0
Subtotal		**39.3**	**35.3**	**68.8**	**67.9**
CD	Uranium Enrichment (from Energy Systems central organizations)	2.5	0	0	0
Total		**41.8**	**35.3**	**45.6**	**47.0**
Percentage of total Laboratory funding		7.7	5.8	5.2	4.5

[a]Figures include operating BA, capital equipment, and construction, if any.

AF—Nuclear Energy R&D

Consolidated Fuel Reprocessing Program • The Consolidated Fuel Reprocessing Program (CFRP) focuses primarily on a broad 5-year collaboration with Japan's Power Reactor and Nuclear Fuel Development Corporation (PNC). Begun in FY 1988, this collaboration supports PNC's effort to develop and to demonstrate technology for reprocessing breeder fuel. PNC and DOE are each contributing $5 million per year to the base R&D program; however, in FY 1992 DOE and PNC have reduced contributions to $3 million per year. DOE has elected not to pursue Phase II, which was to be an additional 5 years composed of new R&D areas coupled with completion of several activities initiated in Phase I. Current plans call for a 1-year extension of Phase I to complete the Chemical Systems Test Solvent Extraction Test Program. In addition, specific hardware is being designed and built in the United States both for the development program here and for the demonstration project in Japan. To date, Japan has fully committed $5.9 million for this hardware. An example of the developed hardware is shown in Fig. 5.19: the remotely maintained, continuous rotary dissolver developed and demonstrated in the United States. Because of the uncertainty in obtaining the export licenses for specific equipment orginally planned to be build in the United States, DOE has elected not to enter into agreements with PNC for the fabrication of the laser disassembly system nor for the centrifugal contactors as originally planned for the Recycle Equipment Test Facility (RETF).

Figure 5.19 Remotely maintained continuous rotary dissolver developed and tested for the Recycle Equipment Test Facility in Japan



The program of collaboration with PNC in LMR reprocessing has focused its R&D activities to support PNC efforts for design, construction, and operation of the RETF in Japan. A follow-on phase was being sought since the operation of the RETF in the late nineties would provide return of demonstrated technology from Japan to the United States (based on RETF operating experience) to help maintain U.S. capability and expertise in this technology area.

The benefits are complementary for both Japan and the United States. PNC is gaining access to much of the breeder-reprocessing technology for oxide fuels that the United States has chosen not to use in the near term. At the same time, because of this program, the United States expects to maintain the core of expertise at ORNL and to seek out additional uses for certain U.S.-developed technologies. In particular, the remote maintenance developments in the CFRP have provided the expertise and motivation for several robotics-related programs at ORNL that are now carried out in several divisions, including a new initiative in the Environmental Restoration and Waste Management Robotics Program that utilizes the technology developed in the CFRP.

The prime areas of interest in the R&D collaboration are (1) centrifugal contactors for solvent extraction; (2) the head-end hardware systems for fuel-element disassembly with lasers, shearing, and continuous dissolution; and (3) overall support to facility maintenance concepts. Other technical exchanges that are rapidly winding down because of limited funding continue at present in (1) a rad-hardening of signal-transmission systems in France and (2) a "hot" demonstration of centrifugal contactors in the U.K. Dounreay fast-breeder reprocessing plant. The R&D for the rad-hardening program was completed in FY 1990. The program is expected to continue with design and data reviews through FY 1993 in order for the United States to obtain operational data from the demonstration at Marcoule. The U.S. contactors for the Dounreay demonstration were provided in FY 1989. Most of the remainder of the program (to be carried out over the next 5 years) will be completed by the U.K. staff; ORNL participation will consist only of review and short-term visits for obtaining operating data.

Transfer of technology to a U.S. firm for the Advanced Servomanipulator has been accomplished, but commercial availability awaits the identification of a specific use. Initial use could be in the ORNL Waste-Handling and Packaging Plant; opportunities are also possible in other U.S. waste management programs and in facilities in Japan and Germany. Broader use of centrifugal contactors is being sought in other DOE facilities and industry for reprocessing and other specialty recovery and process applications. Contactors have been provided to DOE sites at the Oak Ridge Y-12 Plant and at the Idaho Chemical Processing Plant, Idaho Falls, Idaho. We hope that these activities will lead to opportunities to support future DOE fuel-cycle facilities as such needs become better known.

Commercial Reactor Programs • Improved safety, performance, and availability for light-water reactors (LWRs) is an important national need. Responsibility for the evolution of LWR designs is primarily in the hands of industry although DOE still funds design certification and review tasks. ORNL's involvement in LWR development is primarily in the role of design reviews, cost studies, and development of specialized technologies such as passive design features and improved controls systems.

The DOE Liquid Metal Reactor (LMR) Program is shifting emphasis from breeding fissile fuel to actinide recycle. ORNL supports both the reactor design and fuel cycle development portions of the LMR Program. ORNL support to DOE Headquarters (DOE-HQ) for this new actinide recycle initiative includes development and assessment of program plans and recommendations concerning chemical, engineering, and licensing issues. DOE-HQ anticipates that this program will grow substantially in the near future and expects ORNL experience and capabilities to make significant contributions. In the LMR Program ORNL's tasks include advanced controls development, materials development and testing, reliability data base management, robotics, and design review and analysis tasks. Several of the tasks have been cosponsored in recent years by organizations in Japan.

The national MHTGR Program continues on the path outlined in earlier institutional plans, although the funding profiles have never reached the levels requested by the program. The cost-reduction studies by vendor and utility organizations have been completed. They suggest that a larger plant than the reference 350-MW(t) module is required to compete economically. The larger plant [450 MW(t)] has yet to be designed. If the program moves in the direction of the 450-MW(t) plant, there may be some changes to the technology needs to support design. This remains to be seen. Currently there is no financial support for any 450-MW(t) design effort. ORNL's role in the program continues to be technology development in the areas of fuel development, fission product behavior, graphite and metals testing, safety studies, and shielding methods validation. ORNL expects to continue involvement in technology development for the MHTGR until final design is complete and a final safety analysis report has been reviewed by the NRC. The date when this will occur depends on the level of DOE funding for design and technology development and on whether a first order is placed. Current estimates for completion of technology development are 1997 to 2000.

Radioisotope Thermoelectric Generator Production • ORNL continues technical support for the development and fabrication of isotopic-powered and fission reactor power systems. For space missions and terrestrial applications that use heat generated by isotopic power devices, the primary emphasis is on development of improved materials. Activities include the production of iridium alloy clad vent sets to contain heat-generating radioisotopes and carbon-bonded carbon-fiber thermal insulators capable of effective operation at 1300°C. Production of these materials began in FY 1990 and is anticipated to continue through 1993 in support of NASA's Comet Rendezvous Asteroid Flyby (CRAF) and Cassini missions. In January 1992 DOE announced that the CRAF mission had been canceled because of budget shortfalls. The consequences of the decision on RTG manufacturing continue to be evaluated.

SP-100 Program • Under this program ORNL expects to continue in its role in the development and characterization of high-temperature materials and components for fission reactor concepts providing electrical power in the hundreds-of-kilowatt range. In the ground engineering systems phase of the SP-100 Project, ORNL continues to have a significant role in the testing and evaluation of high-temperature materials. In addition, work was initiated in FY 1988 to characterize materials for nuclear shield fabrication and the optimization of a diverse high-temperature sensor. Prototypes of the temperature sensor and the nuclear shield will be fabricated for subsequent testing in the nuclear assembly test to be performed at Hanford, Washington, in the late 1990s. A new development in this program occurred in late CY 1991 when the Strategic Defense Initiative Organization (SDIO) withdrew their funding from the SP-100 Program. SDIO and the Air Force are concerned that the SP-100 Program is costing too much, taking too long, and is not addressing their mission profiles. SDIO and the Air Force feel that the United States should discontinue work on thermoelectric energy conversion and focus instead on the thermionic concept developed by the Soviets. The SDIO and Air Force concerns and point of view have escalated to the Office of Management and Budget, and the future of the SP-100 Program is uncertain.

Office of New Production Reactors • This program was first described as a new initiative in the *FY 1990–1995 Institutional Plan*. During FY 1989 ORNL and the other national laboratories assisted the Office of New Production Reactors (DOE-NP) in development of 5-year technology development plans [later renamed Engineering Development Plans (EDPs)]. In FY 1990 ORNL performed work in areas specified in the EDP, while the design organizations produced two conceptual designs for the HWR (one was selected to go forward into preliminary design) and one for the MHTGR. During fourth quarter FY 1990, DOE, ORNL, and the design organizations refined the EDP to incorporate information developed during the conceptual design phase.

In FY 1991 work proceeded according to the EDPs (as amended). Responsibility for management of much of the EDP work performed at ORNL was transferred for the most part from DOE-HQ to the field. HWR technology development is managed through the Savannah River DOE office and MHTGR work is managed through the Idaho Falls DOE office (DOE-ID). Selected EDP areas are still managed by DOE-NP from Washington. The decentralization in management is driven by the knowledge that the field offices will be responsible for oversight of preliminary and final design, supervision of construction, and operation of the plants once they are built. The technical experience needed to perform these tasks is to be developed through oversight of the technology development and design tasks over the next few years.

In early FY 1992 much of the technology work described in the EDPs was suspended. Work continues only on areas where there is significant technical risk. The pace of work on preliminary design for both concepts has been cut back to about 25% of the FY 1991 pace. A technology down select was scheduled (to accompany the EIS record of decision) in December 1991 but has now been delayed to August 1993. The Administration continues to evaluate future tritium needs in light of the weapons dismantlement program. Options are being reexamined for production of tritium with accelerators. The future of this program is highly uncertain. ORNL will likely continue at about the current rate through FY 1993. Support beyond that is impossible to predict.

As part of the NPR Program, ORNL developed a unique fracture mechanics testing capability for assessing crack growth in large flawed structures subjected to dynamic (fatigue and impact) loadings, such as those imposed during seismic events. The ductile austenitic stainless steel pipe began the test with a premachined through-wall crack located in the center of a circumferential butt weld. The test has demonstrated that while predictable fatigue crack growth occurs, tearing crack growth during the impacts is very small.

The facility has thus yielded data that will allow enhanced safety in DOE's NPR/HWR design without the artificial, costly, and unrealistic constraints imposed by the usual requirement to design for an "instantaneous" double-ended guillotine break in the primary coolant piping. The data provide a convincing demonstration that crack growth involves a finite amount of time and that a double-ended guillotine break is unrealistic. Similar testing may greatly reduce the severity of accident scenarios for other designs. Other flawed components could be tested as well.

Continuing Initiative

Modular High-Temperature Gas-Cooled Reactor Technology Development (Direct Cycle)

One of several unique features of the HTGR is the ability to produce very high temperature working fluid. Coolant outlet temperatures for other reactors in commercial service (LWRs and LMRs) are limited by permissible service conditions for the metallic components in the core and the higher thermal efficiencies in electricity production, and numerous high-temperature advanced applications beyond electricity production. The all-ceramic core HTGR can produce coolant outlet temperatures in the 750°C range with currently available fuels and materials technology. Improved fuel designs and heat transport system materials selections can raise this to 950°C. Developments such as insulating coatings for metallic components and structural ceramics could push this well above 1000°C. For comparison, current LWR and LMR outlet temperatures are in the ranges of 300 and 500°C, respectively.

Development of the HTGR for commercial steam-cycle application is nearly complete. The modular design MHTGR offers safety and investment protection features not available in any other fission reactor concept (Fig. 5.20). However,

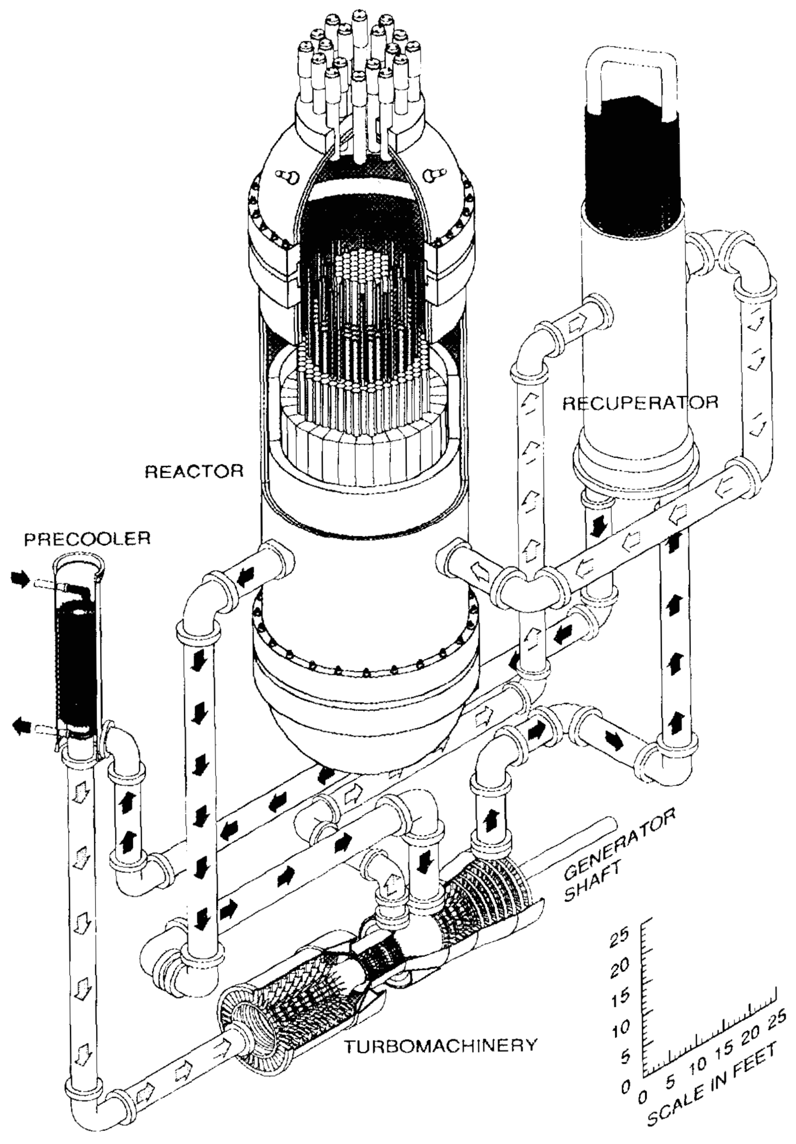


Figure 5.20
Modular high-temperature gas-cooled reactor with direct cycle power conversion (simplified diagram)

economic compromises are required to obtain these attractive features. The MHTGR core has a very low power density compared with LWR and LMR designs (6 W/cc compared with 80 W/cc for LWRs and 300 W/cc for LMRs). The low-power-density, high-heat-capacity MHTGR core can easily dissipate decay heat without requiring active safety systems or operator action. While economies are associated with modular construction and elimination of redundant, active safety systems, the overall MHTGR capital cost had been estimated to be 20 to 30% more than coal plants of the same size. Current program emphasis is to identify design changes that can reduce costs to a level that will make the MHTGR economically competitive.

The increased safety available with gas-cooled reactors is attractive to utilities, to regulators, and to the public. However, both the nuclear industry and the regulatory community agree that currently operating LWRs are sufficiently safe. Neither utilities nor the public is willing to pay more for increased safety margins when the existing product (LWRs) is judged to be adequately safe. Power producers might be willing to pay a premium for increased investment protection, but the large premium currently calculated is judged to be too large. The bottom line is that MHTGR power costs must be reduced to the LWR level before there will be a market.

If the helium outlet temperature can be increased from 700 to 850°C, the MHTGR can be designed to operate in the DC mode. In this mode, hot helium coolant gas for the core is used to drive a turbine directly instead of being sent to a heat exchanger to produce steam, which is used to drive a turbine. The energy conversion area (ECA) for a steam cycle MHTGR represents about half of the estimated capital cost. Simplification of the ECA by replacing the steam cycle components (steam generator, feedwater pumps, feedwater heaters) with a DC balance-of-plant is expected to halve the cost of the ECA, reducing the total plant cost by about 25%. The capital cost reduction, coupled with the higher thermal efficiency (50% for the DC, 37% for the steam cycle), should make the MHTGR-DC cost competitive with LWRs and with fossil plants.

ORNL is now completing a 2-year study on the MHTGR-DC. The purpose of this study is to select the most promising of the many possible design alternatives and to develop defensible cost estimates that can be compared with the alternatives for electricity production (LWR, MHTGR steam cycle, and coal).

The prospects for near-term DOE funding for this concept now appear doubtful. Funding has been dramatically reduced for both the MHTGR-NP and the MHTGR-NE concepts compared with the profiles discussed a year ago (Table 5.15). There is simply no money available to support advanced MHTGR concepts when the baseline steam cycle program is minimally funded.

Table 5.15

Budget projections by fiscal year for the Modular High-Temperature Gas-Cooled Reactor (direct cycle) Initiative[a]

($ in millions—BA)

	1993	1994	1995	1996	1997	1998
Total funding	1.0	0.5	1.0	2.0	3.0	3.0

[a]Funding is being sought under Program AF, Nuclear Energy Research and Development, from the Assistant Secretary of Nuclear Energy, and under Program NP, New Production Reactors, from the Office of New Production Reactors.

Continuing Initiative

Center for Excellence in Research Reactors (See Office of Energy Research Programs.)

New Initiative

Retention of Pool Critical Assembly (See Office of Energy Research Programs.)

Continuing Initiative

Actinide Recycle

DOE has recently redirected the focus of its LMR programs toward actinide management and away from breeding. If long half-life actinides can be removed from spent LWR fuel and recycled in a fast reactor, the burden on the spent fuel repository will be reduced. Further, management of the residual short half-life fission products will require a shorter period of institutional care. ORNL has a broad experience in many areas to offer to the emerging DOE actinide recycle program:

- fuel cycle analysis,
- equipment design,
- reprocessing flowsheet development and evaluation,
- waste form testing and evaluation,
- robotics,
- NEPA analysis, and
- proliferation analysis.

Table 5.16 outlines the projected budget for the Actinide Recycle Initiative.

Table 5.16

Budget projections by fiscal year for Actinide Recycle Initiative[a]

($ in millions—BA)

	1993	1994	1995	1996	1997	1998
Total funding	**2.0**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**

[a]Funding is being sought under Program AF, Nuclear Energy Research and Development, from the Assistant Secretary for Nuclear Energy.

Continuing Initiative

Nuclear Propulsion for Space Exploration Initiative

A new Bush administrative space initiative was announced in July 1989. The SEI focuses on colonization of the moon and a manned expedition to Mars. Success of the SEI will most probably depend upon use of nuclear propulsion. An extensive SEI planning effort has been in progress during the last 2 years, supported primarily with Laboratory and industrial internal R&D funds. Unfortunately, none of the sponsoring agencies (DOE, DOD, and NASA) has appropriated funds to support either the planning or implementation of the planning. Budget projections for the Oak Ridge Space Program for FY 1993–1998 are shown in Table 5.17.

If the Congress commits to an SEI program, it will be a major effort. The preliminary budget estimate for the nuclear propulsion element alone, from FY 1991 through FY 2006, was $4 billion. The broad objectives of SEI include space stations, manned colonies on the moon, and travel to Mars by 2019. The near-term focus of SEI will be technology development:

- search for new, innovative approaches and technology;
- investment in high leverage, innovative technologies with potential to make a major impact on cost, schedule, and/or performance; and

Table 5.17
Budget projections by fiscal year for the Oak Ridge Space Program[a]
($ in millions—BA)

	1993	1994	1995	1996	1997	1998
Total funding	**0.8**	**2.0**	**5.0**	**8.0**	**10.0**	**12.0**

[a]Funding is being sought from the Assistant Secretary for Nuclear Energy and other DOE sources, from NASA, and from DOD.

- mission, concept, and systems analysis studies.

Preliminary planning efforts have focused on eight technology areas:

- space transportation,
- in-space operations,
- surface operations,
- human support,
- lunar and Mars science,
- information systems,
- automation, and
- nuclear propulsion.

ORNL's major interest is nuclear propulsion. The focus of nuclear propulsion technology development will be nuclear thermal rocket propulsion capable of long life and multiple starts and nuclear electric propulsion.

ORNL's approach to SEI planning will be

- to identify areas where ORNL can contribute to SEI by reviewing past work on nuclear propulsion for space applications and approaches being discussed for the future;
- to inventory facilities, equipment, and personnel assets in those areas;
- to develop specific proposals (scope, schedule, and cost estimates) for deployment of assets to provide data and to demonstrate feasibility to support the first phase of SEI nuclear propulsion development;
- to contribute to development of task plans for technical areas listed in SEI program plan; and
- to enhance perception within the technical community regarding ORNL's expertise and credentials by organizing and hosting technical workshops.

AJ—Naval Reactors

Radiation Shielding Information Center • The performance of radiation protection, transport, shielding, and related studies for Nuclear Energy (NE) programs requires specialized information, computational tools, and a suitable cross-section data base. The Radiation Shielding Information Center (RSIC) provides these by serving as a focal point in the community for technology exchange, making available latest developments in computing and other technology, data libraries, and bibliographic information. The technology base is continually improved through contributions from the user community of new technology or improvements made to existing tools. Special data needs addressed by RSIC are generating, validating, and upgrading specific data libraries needed by the shielding community, including persons working on problems essential to NE programs.

Specific activities of RSIC include operating a computer-based information system and answering inquiries on radiation analysis; collecting, testing, packaging, and distributing computer codes and evaluated and processed nuclear data libraries; collaborating in work on standards and in the generation of needed multigroup cross sections; leading American Nuclear Society (ANS)-6, Radiation Protection and Shielding Standards Subcommittee; and holding seminars and workshops.

The addition of literature to the RSIC collection will be continued, and revised bibliographies and additional abstracts will be issued. Publication of the *RSIC Newsletter*, which keeps RSIC in continuous contact with its user community, will continue.

The value of the computer code and data exchange service has been established, giving rise to a continual increase in requests, which is not expected to saturate soon. Acquisition of information, codes, and data will continue in all areas. Efforts will be made to improve continuously methods for information dissemination and for evaluation through feedback. Updated bibliographies and additional computer code and data abstracts will be issued.

Work will continue as practicable in the long-term effort to compile basic transport and milestone data. Work on standards in collaboration with the American Nuclear Society will continue. RSIC will continue to support the National Nuclear Data Center, the Cross Section Energy Working Group, and all other efforts to make available more and better cross sections and provide adequate benchmarks for verification of computational techniques and data.

KK05—Policy and Management Support for DOE's Office of Nuclear Energy

DOE Standards Program in Support of the Office of Nuclear Energy • Since the late 1960s, ORNL has led in the management and overall conduct of the DOE (then the Atomic Energy Commission) standards development efforts. In this position, ORNL has been responsible for establishing the program procedures and guidance for all participating DOE and DOE contractor organizations to implement DOE's standards policy as outlined in Order 1300.2, *Department of Energy Standards Program*. Order 1300.2 is currently under revision and will be issued in 1992. The updated order will reaffirm the department's long-standing policy to use existing national/international standards or develop new departmental standards for its facilities, programs, and projects. ORNL responsibilities for the DOE Standards Program are being expanded

- to function as the DOE lead standardization organization serving as the focal point within the department for registering new and ongoing standards development activities and carrying out technical/administrative program management;
- to develop new program procedures and a DOE standards program manual for all involved organizations to follow to implement the DOE standards policy;
- to develop a DOE standards index, identifying the various types of standards (international, nongovernment, federal, DOE, and program-specific) used or available for use by DOE and DOE contractor organizations and departmental and contractor personnel involved in standards development activities;
- to develop and conduct training (initial and ongoing) for DOE and DOE contractor personnel on the new DOE Standards Program procedures; and
- to provide technical support for a DOE standards committee to arbitrate standards development/application issues that affect more than one department secretarial office.

DOE Performance Indicator Program in Support of the Office of Nuclear Energy • ORNL assisted DOE in 1991 in establishing a DOE-wide system for trending and analyzing operational data to help assess and support progress in improving performance and to strengthen line management control of operations relating to ES&H activities. DOE, in a manner similar to the commercial nuclear industry, considers that facilities with good performance, as measured by an overall set of performance indicators, are generally recognized as well-managed facilities. The department's objective is to collect data on key performance indicators and to have line management analyze and trend the data. ORNL assisted in developing the methodology for presenting and analyzing the data; provided training on the program to all DOE sites, DOE headquarters, and contractors; and prepared summary-level reports. ORNL currently compiles and prepares quarterly summary reports based on similar quarterly reports received from the DOE program senior officials and performs special analyses of this data as requested.

ST—Isotope Production and Distribution Program

The mission of the Isotope Production and Distribution Program at ORNL is to supply enriched stable isotopes, selected radioisotopes, and related technical services for use in research, medical, and industrial applications. The production of radioisotopes and enriched stable isotopes continues to be a significant and highly valued program that uses the unique capabilities and facilities located at ORNL. Radioisotopes for many uses including medical research are produced in the HFIR; enriched stable isotopes are produced in the Calutron Facility. The mission also includes the development and evaluation of methods for isotope production and separation. Various stable isotope enrichment projects are evaluated for production in the gas centrifuge facilities at the K-25 Site. Specialized technical services such as preparation of high-purity isotopes and unique chemical and physical forms are also performed. Although the program was partially funded by the Office of Energy Research prior to 1990, it has operated since then under a "revolving fund" arrangement that is supposed to be self-supporting. The program has taken numerous actions to implement the revolving fund and, because foreign competition has reduced sales, to keep the program costs within available funds. These actions include conversions of isotope loans to leases, reprocessing of returned material, placing the Calutron Facility and the Isotope Research Materials Laboratory in standby, and reassigning program staff. Table 5.18 shows the recent

Table 5.18
Summary of Isotope Production and Distribution Program funding performance
($ in thousands)

	FISCAL YEAR			
	1990	1991	1992[a]	1992[b]
Funding	10,739	7,042	3,200	4,650
Expenses	10,305	6,875	2,975	4,630
Revenues	12,558	4,624	2,552	6,740

[a]Actual costs for October 1991 through February 1992.
[b]Projections for March through September 1992.

funding experience of the program. Revenues have come primarily from sales of radioisotopes and from the inventory of enriched stable isotopes. ORNL's ability to operate within the program's funding constraints has been possible because managers and staff of other programs have been flexible and cooperative, allowing us to support temporary staff to meet program obligations without maintaining a full staff at program expense. ORNL will continue to try to carry out missions associated with this program but may experience difficulty in meeting production schedules within the current funding constraints.

Office of Nuclear Safety

NS—Nuclear Safety

The purpose of this task is to assist the Office of Nuclear Safety in the analysis of operational data from DOE facilities (Table 5.19).This information will be obtained generally from reports submitted pursuant to DOE Order 5000.3A or other formal reporting requirements. The Nuclear Operations Analysis Center at ORNL will conduct engineering evaluations of events; participate in audits of the reporting requirements; prepare reports on events analysis, cause, and corrective action evaluations; event categorization; and trends and patterns analyses. The center conducts other operational information reviews related to specific facilities or groups of facilities.

Table 5.19
Office of Nuclear Safety major program summary
($ in millions—BA)[a]

Budget and reporting code	Major program	FISCAL YEAR 1991	1992	1993	1994
NS	Nuclear Safety	0.1	0.2	0.3	0.3
Percentage of total Laboratory funding		<0.1	<0.1	<0.1	<0.1

[a]Figures include operating BA, capital equipment, and construction, if any.

Office of New Production Reactors

The ORNL NPR Program (Table 5.20) is focused into four primary areas:

- materials and structures development in support of the NPR HWR;
- materials development in graphite, in-reactor metals and ceramics, vessel materials, and heat transport system (primarily steam generator) materials for the NPR MHTGR;
- confirmatory development in fuels, fission product transport, reactor physics and reactor vessel fluence shielding for the NPR MHTGR under funding from, and technical direction by, the NPR Department at EG&G Idaho, Inc.; and
- confirmatory cost analysis and evaluations to support all tritium-production options, including the accelerator.

The urgency for new production capacity continues to lessen because of major world events such as the breakup of the Soviet Union and the agreements to reduce nuclear stockpiles. The NPR Program EIS has now been folded into the weapons complex reconfiguration program EIS, which is to be completed in August 1993. This represents a delay of at least 2 years.

Table 5.20
Office of New Production Reactors major program summary
($ in millions—BA)[a]

Budget and reporting code	Major program	FISCAL YEAR[b] 1991	1992	1993	1994
NP	New Production Reactors	10.1	10.4	1.0	0.6
Percentage of total Laboratory funding		1.9	1.7	0.1	<0.1

[a]Figures include operating BA, capital equipment, construction, and proposed construction but not the funds by reconciling transfer from DOE-ID to EG&G Idaho.
[b]Out-year numbers assume a favorable MHTGR decision at record of decision.

Efforts that support the record of decision include

- preparation of cost studies;
- demonstration testing of HWR primary system piping to show that the double-ended guillotine break is not a credible design basis accident for HWR plant conditions—simplifying the design of HWR emergency core cooling systems and making the safety case for categorizing core damage events as beyond design basis;
- identification of alternate coke sources for long-term graphite supply including (1) a joint effort with Great Lakes Carbon to qualify nuclear grade H-451 from alternate coke sources, (2) support for the DOE grant to the University of West Virginia to develop a domestic source of coal tar–based nuclear graphite using clean coking technology and minimizing sole reliance on petroleum coke sources, and (3) joint efforts with other graphite vendors to identify alternate materials equivalent to H-451;
- joint-testing programs with ABB Combustion Engineering to establish the corrosion resistance of the candidate Alloy 800 material for the NP-MHTGR steam generator; and
- irradiation testing of MHTGR fuel to identify the cause of previously observed failures of coated-particle fuel and to demonstrate that low in-pile failure rate of coated fuel particles can be achieved with U.S.-fabricated fuel.

To better support the NPR Program, ORNL has formed an NPR project office within the Metals and Ceramics Division and has assigned or detailed all project personnel working full time on NPR development activities to the project office. In addition, a full-time quality assurance manager has been assigned to support the project director. An NPR Records Management System has been created to provide controlled, indexed, and protected retrievable storage of NPR quality assurance records generated by the project.

Assistant Secretary for Defense Programs

Programs sponsored by the Assistant Secretary for Defense Programs include Weapons Activities, Safeguards and Security, Materials Production, and Defense Waste and Transportation Management (Table 5.21).

Table 5.21

Assistant Secretary for Defense Programs major program summary

($ in millions—BA)[a]

Budget and reporting code	Major program	FISCAL YEAR 1991	1992	1993	1994
GB	Weapons Activities	0.0	0.2	0.5	0.5
GD	Nuclear Safeguards and Security	0.6	0.4	0.5	0.5
GE	Materials Production	6.9	10.7	14.3	12.5
Total		**7.5**	**11.3**	**15.3**	**13.5**
Percentage of total Laboratory funding		1.4	1.9	1.7	1.3

[a]Figures include operating BA, capital equipment, and construction, if any.

GB—Weapons Activities

DOE Emergency Management • ORNL will provide assistance as needed in reviewing, revising, and implementing the DOE Emergency Management System. Specific tasks may include assistance in the following:

- developing DOE orders and guidance,
- developing criteria for readiness assurance,
- developing criteria for a coordinated exercise program and reviewing implementation of those criteria,
- training emergency management teams,
- participating in appraisals of emergency management and evaluations of exercises, and
- assisting in exercise development and scenario review.

This work will contribute to an improved emergency management system and a more consistent and effective exercise program.

GD—Nuclear Safeguards and Security

GD0601—Detection of High Explosives by Mass Spectrometry/Mass Spectrometry • High-sensitivity/high-specificity detection of the vapors of high explosives is being approached by the combination of atmospheric sampling glow discharge ionization coupled with tandem mass spectrometry. The quadrupole ion trap is being developed as the tandem mass spectrometer. Work leading to the present state of the art has demonstrated this technology to be capable of detecting explosives vapors at concentrations as low as a few parts per trillion with essentially no false alarms. Efforts over the next 5 years are focused on improvements in the glow discharge source; new techniques for ion injection; engineering to ruggedize and automate the detector; and coupling with sampling/preconcentration systems to address the screening of personnel and items such as packages and vehicles.

GE—Materials Production

This program includes the Mark 42 Processing Program, the ^{252}Cf Industrial Sales/Loan Program, and the ^{233}U Storage and Distribution Program. The Mark 42 Processing Program involves the recovery and purification of transuranium element isotopes (^{242}Pu, ^{243}Am, and ^{244}Cm) from Mark 42 targets that were previously irradiated at the Savannah River Site and disassembled at Pacific Northwest Laboratory. The transuranium element isotope products will be used in weapons diagnostics studies at LANL and Lawrence Livermore National Laboratory. One Mark 42 target will be processed each year in the REDC at ORNL, and the program is expected to continue for about 10 years. Preparations for processing were made in 1989 and 1990, and processing began in 1991.

The ^{252}Cf Industrial Sales/Loan Program is carried out to supply ^{252}Cf to fabricate neutron sources for medical, research, and industrial uses. This work is done in the Californium Facility in the REDC, Building 7930.

Shielded, safeguarded storage and some distribution of ^{233}U continue in the Radiochemical Development Facility (Building 3019) at ORNL. Equipment for processing ^{233}U has been in standby since 1989. Plans are being developed to improve the condition of the aging facility to ensure safe, long-term storage and distribution of ^{233}U and safe, long-term standby of the processing equipment. Preparations continue to provide for the safe storage in Building 3019 of mixed (plutonium and uranium) oxide scrap that was generated at the Nuclear Fuel Services Plutonium Facility in Erwin, Tennessee. The receipt of this material is anticipated in 1992.

Assistant Secretary for Conservation and Renewable Energy

ORNL conducts research and provides field management on a wide range of programs for the Assistant Secretary for Conservation and Renewable Energy (Table 5.22). Ultimate goals are to increase energy efficiency and the use of renewable resources. This will help increase our industrial competitiveness and to reduce our dependence on oil imports, the cost of energy to consumers, and the environmental impact of energy production and conversion activities.

Table 5.22

Assistant Secretary for Conservation and Renewable Energy major program summary

($ in millions—BA)[a]

Budget and reporting code	Major program	FISCAL YEAR 1991	1992	1993	1994
AK	Electric Energy Systems	7.5	10.1	11.5	12.9
AL	Energy Storage Systems	1.2	0.8	0.2	0.0
AM	Geothermal Energy	4.7	0.4	0.4	0.4
CE	Hydropower	0.2	0.3	0.3	0.3
EB	Solar Energy	4.6	4.6	6.1	6.4
EC	Buildings Sector	14.4	12.0	13.3	17.9
ED	Industrial Sector	1.9	8.9	12.3	13.4
EE	Transportation	20.6	24.9	30.4	37.8
EF	Technical and Financial Assistance	2.0	2.4	1.0	1.0
EG	Multi-Sector	6.1	0	0	0
EK	Utility Sector	0	1.1	0.9	0.9
Total		**63.2**	**65.5**	**76.4**	**91.0**
Percentage of total Laboratory funding—BA		11.6	10.8	8.6	8.7

[a]Figures include operating BA, capital equipment, and construction, if any.

Particular effort is made to ensure that the research is responsive to industry needs and that research results are made known to industry in a form that will encourage immediate use. The use of CRADAs, starting in FY 1991, has markedly increased our ability to work with industry. Operation of two Conservation Program user facilities, the HTML and the Roof Research Center, has also been a key element in interactions with industry.

In FY 1992 the transportation sector is receiving greatly increased emphasis at both the DOE and ORNL levels. The DOE/CE budget request for FY 1993 includes an increase of 47% for transportation sector programs. ORNL funding in transportation (Program EE) increased by 16% from FY 1991 to FY 1992 and is projected to increase by an additional 29% in FY 1993. These projections do not include new initiatives on electric hybrid vehicles that are now under discussion with automotive companies. This and other transportation initiatives may result in substantial increases in future years.

Noteworthy changes in expected funding levels of other programs are the following. Program ED is expected to have substantial increases in Continuous Fiber Ceramic Composites and Alternate Feedstocks for Chemicals. Program EK will decrease because of the termination of District Heating, Cooling, and Cogeneration; and Program AL will end with the termination of Thermal Energy Storage. The budget request for Program EB indicates an increase, but this is uncertain because of the proposed transfer of the biomass feedstock research to the U.S. Department of Agriculture (USDA).

AK—Electric Energy Systems

The discovery of ceramic superconductors that can operate at temperatures as high as 77 K offers the potential for many applications of superconductivity that were previously thought impractical. The ORNL Superconductivity Technology Program seeks to develop, with industry, the technology base for development of electric power applications. To expedite and encourage projects with industry, DOE established a novel set of business arrangements known as Pilot Center Cooperative Agreements. Provisions regarding ownership of intellectual property are flexible, safeguards of proprietary data are available, and a simplified model agreement is followed. These arrangements have stimulated intense industrial interest. Twenty-three cooperative agreements had been signed by the end of FY 1991. In a number of these projects, ORNL is working with industry to develop processes for converting powder precursors into high-performance superconductors (Fig. 5.21). Several cooperative agreements involving magnet design and testing are under way or in final negotiation. A prototype magnetic refrigerator stage that could provide 50-W cooling at 35 K is being developed in a cooperative agreement with Astronautics Corporation of America.

The ORNL Power Systems Technology Program continues to develop and implement transmission and distribution technologies for electric utility systems (Fig. 5.22). The effort

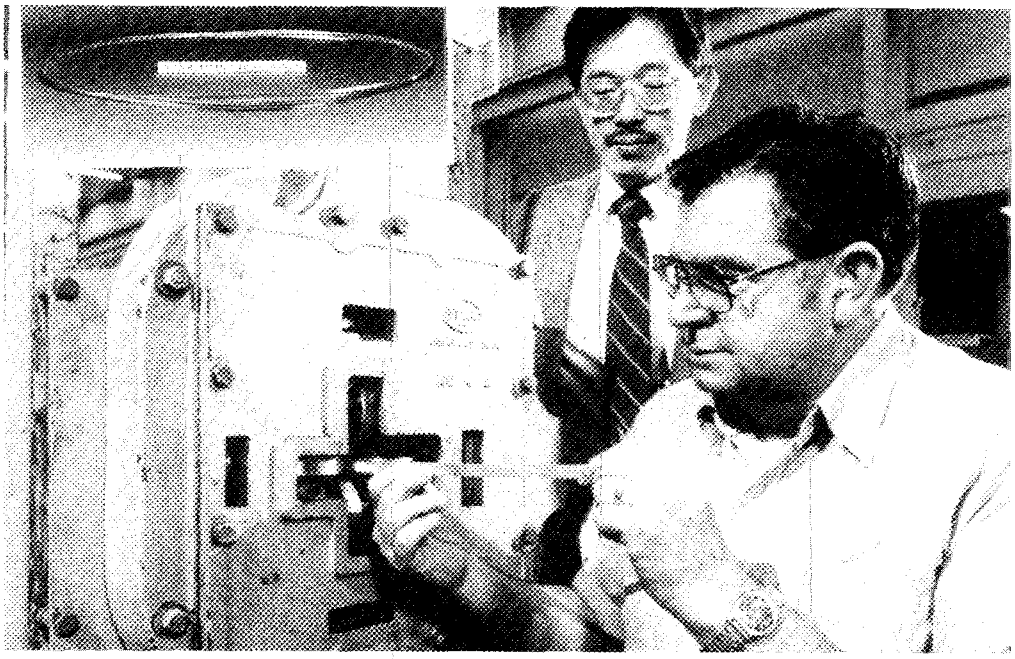


Figure 5.21 ORNL researchers use drawing and rolling equipment to fabricate long lengths of high-temperature superconducting tape. This research is carried out in collaboration with American Superconductor Corporation.

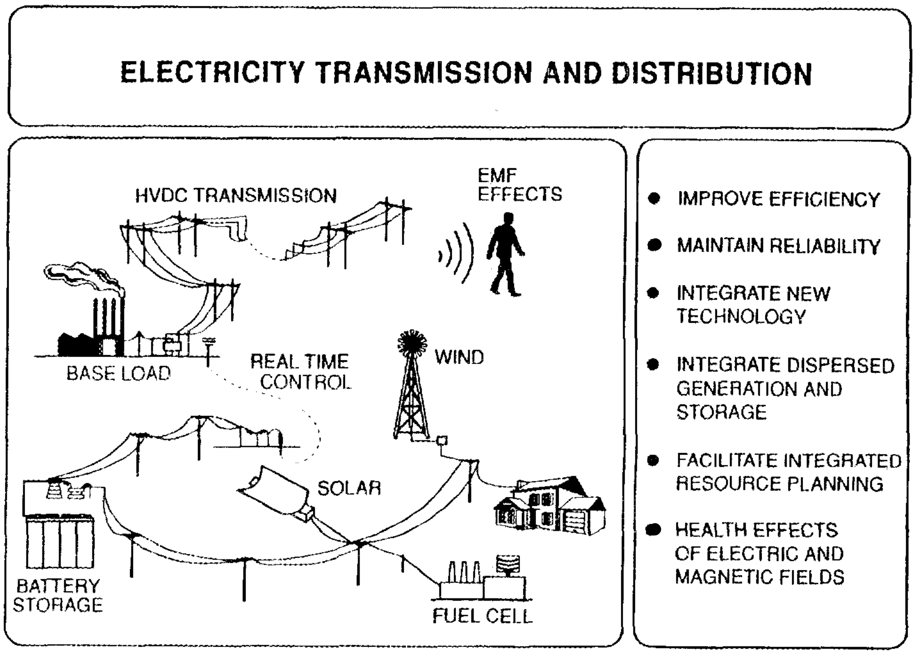


Figure 5.22 Challenges in planning the power grid of the future include integration of renewable resources and energy storage, expansion of integrated resource planning, implementation of real-time power control, and health effects of electric and magnetic fields.

focuses on technologies to decrease system losses, to increase power-handling capability, and to ensure reliable operation. Reliability is being improved by analyzing the effects of geomagnetic disturbance, electromagnetic pulse, electromagnetic interference, lightning, and problems of surges and power quality. Production, detection, and mitigation of S_2F_{10} from SF_6 gas insulators is being studied in a CRADA.

ORNL is working with the Office of Energy Management to develop and conduct a program on electric and magnetic field effects. This program is expanding as DOE fills the lead agency role in the new National Electromagnetic Field Effects Program. The expanded program will include communications and engineering elements in addition to an enhanced science research element.

In future years the funding for high-temperature superconductivity (a former ORNL initiative) is expected to increase. New initiatives are being developed in areas of real-time power control, high-voltage direct current transmissions, and distributed generation. Power Systems Technology and Electric and Magnetic Field Effects are also expected to have increased funding during FY 1993 and FY 1994.

AL—Energy Storage Systems

For 12 years, ORNL has conducted a program to develop thermal energy storage technologies for industries and buildings. These technologies are used to store energy in the form of sensible or latent heat and to release this heat at a later time to meet a heating or cooling need.

At present, the program consists of four cost-shared, subcontracted research projects to develop systems for storing heat in wallboard, water heaters, off-peak refrigeration, and high-temperature industrial processes. The program will be closed out in FY 1993.

AM—Geothermal Systems

ORNL participates in two areas of the Geothermal Program. In the first, we are providing technical and analytical support to the DOE Geothermal Division for the preparation of an EIS for the Hawaii Geothermal Project. The project consists of testing the geothermal resource on the island of Hawaii, demonstration of the deep-water cable between Hawaii and Maui, and construction of commercial geothermal power production facilities on Hawaii.

The second project consists of a continuing series of studies that provide input data for models of chemical reactions in geothermal systems. Some important consequences of such reactions include reservoir plugging, scaling of heat transfer surfaces, and excessive corrosion.

The first project is expected to be completed in FY 1993, whereas the second will continue during the planning period.

CE—Hydropower

This project provides research and other technical assistance to DOE-HQ and DOE-ID on environmental aspects of the Hydroelectric Systems Program. In FY 1992 the first volume of the Environmental Mitigation Study was completed, providing an objective basis for identifying environmental research priorities and for selection of mitigation practices. The second volume will be completed in FY 1993 and will focus on fish-passage issues at dams. Hydropower funding is expected to continue at about the present level.

EB—Solar Energy

The Biofuels Feedstock Development Program provides field management for a national program of research on terrestrial energy crops, supporting research and analysis at ORNL, and technical assistance to DOE's Biofuels Systems Division. The program goal is to develop technologies for producing large quantities of low-cost, high-quality biomass feedstocks.

The program is closely coordinated with biofuels conversion research at the National Renewable Energy Laboratory. Production questions at the technical research level are being addressed in a complementary manner for both herbaceous and woody crops. The linkages between feedstock quality and conversion technologies are specifically considered in the genetic development of species as energy feedstocks.

Significant recent research accomplishments include the following. Successful development of tissue-culture techniques for more than 60 genotypes of silver maple has enabled provenance trials using tissue-cultured plantlets. Farm-scale models, regional evaluations, and national-scale analysis efforts are providing better information for forecasting locations and types of land potentially available for biomass production. Atmospheric carbon mitigation benefits gained from use of biofuels and biomass electricity were determined. Figure 5.23 shows an example of the "carbon balance" for a wood-to-ethanol plant.

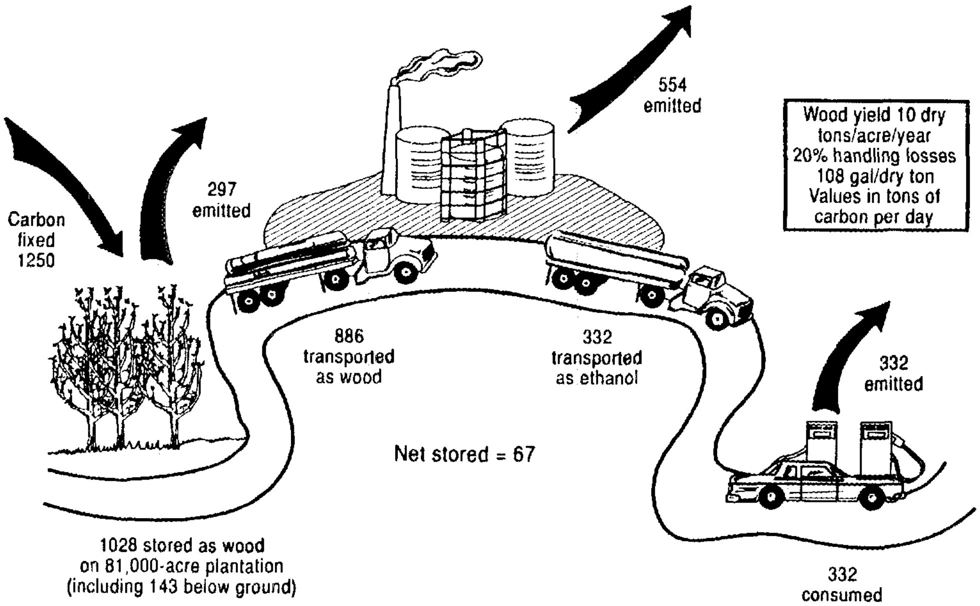


Figure 5.23
ORNL's Biofuels Feedstock Development Program is evaluating the environmental effects of biomass-based fuel cycles.

Research during the planning period is expected to make steady progress toward the ultimate goal of economic and environmentally sound biofuel feedstock production. Specific milestones include final reports from herbaceous screening studies in the Great Plains and reports on the results of environmental monitoring in energy crop field trials in FY 1993. Selection of preferred switchgrass varieties for the north-central region and completion of the genetic map of a hybrid poplar (the first for a forest tree) will be completed in 1994.

ORNL proposes substantial increases in funding for biofuels feedstock in future years in order to meet National Energy Strategy goals for fuels from biomass. At the same time we are working with DOE-HQ in an effort to transfer responsibility for biofuels research to the USDA. If the interagency transfer is successful, the content and size of the ORNL program may change during the planning horizon.

An evaluation of the Regional Biomass Energy Program began in FY 1992 and is expected to continue through FY 1994. Other small projects in Program EB are being completed during FY 1992.

EC—Buildings Sector

ORNL is responsible for field management in four program areas: Building Thermal Envelope Systems and Materials (BTESM), Existing Buildings Research, Building Equipment Research, and Buildings Technology Transfer. The BTESM project seeks to identify cost-effective improvements in the design of walls, roofs, foundations, and component materials. FY 1992 saw the publication of *Moisture Control Handbook for New, Low-Rise Residential Construction*, containing a number of viable solutions to moisture problems. Follow-up studies are in progress to define more clearly the relationships among climate, design, and building operation so that cost-effective methods for controlling moisture levels can be specified.

A shortened and revised version of the *Buildings Foundation Design Handbook* was completed and published in 1991. It is estimated that full compliance with cost-effective foundation insulation would save an additional 0.2 quads/year for new buildings. In order to encourage more widespread compliance, an integrated experimental validation effort on slab and basement designs will be started in FY 1992.

Work is continuing on alternative blowing agents to replace CFCs in closed-cell foam insulation. Principal future activities include development of a technical data base for use in a proposed American Society for Testing and Materials test procedure on cellular plastic foam materials. Also, an assessment will be made to determine the typical level of performance in commercially available wall systems as well as in novel systems.

The Roof Research Center continues to be used on important collaborative projects with industry such as the degradation of thermal performance of loose-filled attic insulation because of convective heat transfer in the insulation. The *Roof Research User Manual* and *Strategic Plan* will be updated during FY 1992.

A major thrust of the Advanced Materials project is the development of powder evacuated panels (PEPs). These insulation panels are evacuated to reduce heat flow and contain high-thermal-resistance powder to provide structural support without introducing thermal bridges. In FY 1991 a CRADA was initiated with the Appliance Research Consortium to determine the lifetime of PEPs. Additional work was done on determining PEP performance as a function of pressure and powder type. Future research will concentrate on development of cost-effective powders and barrier materials that also yield high performance.

The goal of the Existing Buildings Program is to improve the effectiveness of conservation retrofits by increasing the understanding of how retrofit measures actually affect energy efficiency. Projects are identified and carried out by competitive procurements. Participants include state weatherization agencies, utilities, city governments, and the Alliance to Save Energy. Figure 5.24 shows building retrofit measures being evaluated in different parts of the United States.

Building Equipment Research seeks to conserve energy by developing improved heat pumps for heating and cooling buildings. Both electrically driven and heat-actuated

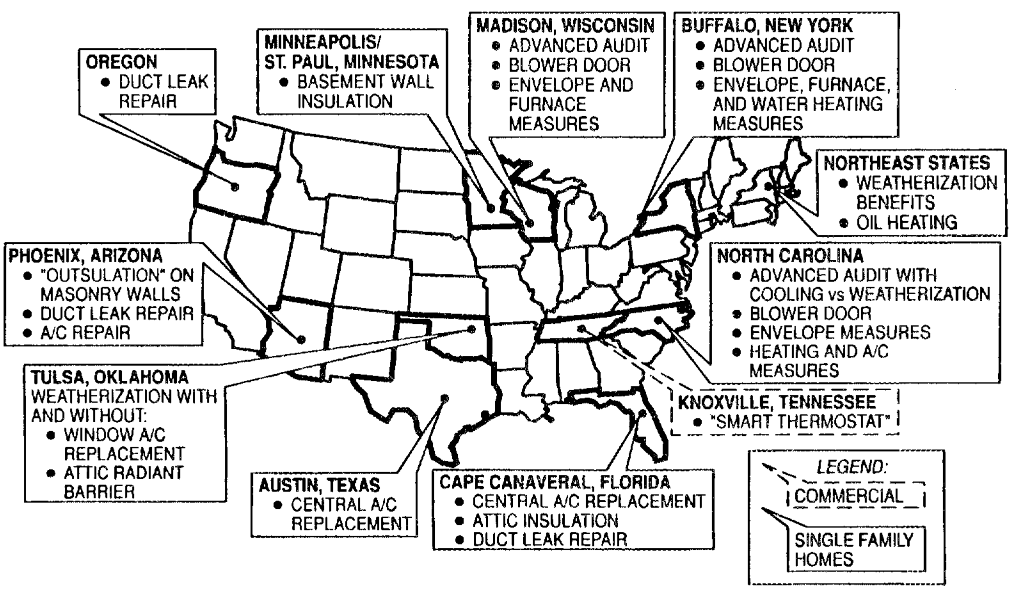


Figure 5.24 In the Existing Buildings Research Program, field-monitoring projects are providing building retrofit performance results from across the country.

heat pumps are included. A major goal is to facilitate and expedite U.S. industry's transition from CFCs to acceptable, atmospherically safe alternatives that provide equal or better energy efficiency. Research activities for electrically driven systems include testing of CFC alternatives and refrigerant mixtures. Several advanced concepts of heat-actuated heat pumps are under development by industrial subcontractors for both residential and commercial applications. The new cycles under development operate with 30 to 50% higher efficiency than the double-effect chillers commercially available today. During the first half of FY 1993 we expect to complete residential generator-absorber heat exchange absorption heat pump engineering test units and to begin the transition from research to commercialization of the technology.

The purpose of the Buildings Technology Transfer Program is to foster the adoption of energy-efficient and renewable buildings technologies developed by DOE and also those developed by the private sector. A specific activity is a cooperative project with the National Association of Home Builders Research Center to identify emerging technologies useful to the home-building industry. Other technology transfer activities include coordination with organizations such as the Conservation and Renewable Energy Inquiry and Referral Service and the Office of Scientific and Technical Information.

Moderate increases in budget levels of the buildings program are expected during the planning period.

ED—Industrial Energy Conservation

ORNL performs applied R&D on four projects for the Advanced Industrial Concepts (AIC) Division. The AIC Materials project develops new and improved materials and manufacturing technologies in collaboration with industry. Some of the tasks being addressed are the following. High-temperature ordered intermetallic alloys are being developed with high strength, ductility, and corrosion resistance. Metal-bonded composites are being developed for use at temperatures between those of metal alloys and ceramics. Advanced catalyst materials are being developed to improve combustion processes and to minimize emissions. Microwave technology is being applied to produce materials with unique properties. Surface modification of polymers is also being explored to obtain superior properties. Recent significant achievements include development of a weldable Ni_3Al and the initiation of a CRADA with General Motors on development of Ni_3Al heat-resistant furnace assemblies. As a result of earlier developments, patent licenses were signed in FY 1992 for the use of a variable-frequency microwave source and production of TiB_2 reinforced with continuous-filament ceramic fibers. An R&D 100 award was received for a metal purification method using magnetohydrodynamics.

A second AIC project is Advanced Bioprocessing Concepts. Fluidized-bed bioreactors with immobilized cells are being studied for both three-phase and four-phase operation, including an extraction phase to combine fermentation and separation. This development will ultimately improve the economics of producing various organic chemicals. Technical feasibility was demonstrated in FY 1991 for lactic acid. Gas-phase bioreactors are also being examined with an emphasis on immobilized biocatalysts.

Additional AIC projects are the development of microemulsions as low-emission alternative transportation fuels and thermal science research to investigate advanced concepts such as superconducting magnetocaloric energy conversion and heat-pipe heat transfer. A proposed project for FY 1993 is the use of electric fields to enhance industrial chemical processing.

ORNL is performing R&D on three projects for the Industrial Energy Efficiency Division. The Continuous Fiber Ceramic Composite project focuses on the development of the primary processing methods for fabrication of this important class of materials. Two tasks have been assigned to ORNL. Under Assessment and Support, ORNL assisted DOE in developing the program plan in FY 1990 and continues to provide technical assistance in evaluation of projects and in interactions with industry. The second task, Supporting Technologies, consists of R&D on the more basic or generic elements of (1) composite design, (2) materials characterization, (3) test method development, and (4) database and life prediction. This research will provide the scientific foundation for successful process development and scaleup.

A continuing project for the Industrial Energy Efficiency Division is Materials for Advanced Industrial Heat Exchangers. This project provides materials technology support to DOE and its contractors for advanced heat exchangers made of metal alloys or ceramics. The cost, performance, and reliability of the heat exchanger must meet high standards under operating conditions that are typically extremely corrosive. In the Chemical Heat Pump project, ORNL has assisted DOE in selecting two promising technologies for industrial demonstration. The emphasis in FY 1992 and the following years will be the development and implementation of a program plan for a "Zero Emission Boiler," which is a heat pump that can replace boilers and not produce air emissions.

A new program for the Improved Energy Productivity Division in FY 1992 is Alternative Feedstocks for Chemicals and Petroleum Refining Industries. This program is part of a bioprocessing initiative with participation by four national laboratories. During the initial planning and assessment phase, ORNL will be responsible for evaluation of advanced techniques for feed preparation, bioconversion, and downstream processing.

Two smaller FWPs in Program ED provide analytical support for the Office of the Assistant Secretary for Conservation and Renewable Energy.

The programs on Continuous Fiber Ceramic Composites and Alternative Feedstocks for Chemicals and Petroleum Refining are scheduled for increased funding levels in future years. The other research programs in Industrial Technologies are expected to have relatively stable funding. In addition, several new initiatives are under discussion for possible future funding, including waste minimization technologies and stationary gas turbines.

EE—Transportation

R&D to improve transportation efficiency and to develop alternative fuels is critically important for meeting National Energy Strategy goals on energy security, economic efficiency, and environmental quality. ORNL now participates in DOE programs on transportation materials, propulsion technology, alternative fuels, transportation data, and policy analysis. ORNL has designated transportation as one of eight Laboratory initiatives, indicating that high priority is given to increasing the scope of programs in this area. (See Sect. 4, "Summary of Major Initiatives.")

Recent discussions with the major U.S. automotive companies have indicated a strong desire by these companies to work cooperatively with ORNL and the other national laboratories on advanced technologies, including hybrid vehicles. By February 1992 one CRADA was signed with General Motors, and a number of other CRADAs were under discussion. It is an ORNL goal to translate these discussions into a comprehensive set of R&D programs to assist the automotive industry in becoming more competitive, increasing the fuel efficiency of vehicles, and utilizing domestic energy resources.

Our major current project for the DOE Office of Advanced Transportation Materials is the Ceramic Technology Project. This project is developing the industrial technology base for reliable, cost-effective components in advanced automobile and truck (diesel and gas turbine) engines. The energy-savings potential of ceramics is based primarily on higher operating temperatures and secondarily on reduced friction, weight, and inertia. The major part of the work is done through cost-shared subcontracts to the ceramics industry. The project is proceeding toward a set of performance, reliability, and cost goals defined by a multiyear plan. The materials technology is being developed in close coordination with ongoing DOE and industry engine development programs. Since 1983, many of the performance objectives for advanced ceramics have been met, and the emphasis has shifted to cost reductions. Detailed plans for our efforts in this area are given in an FY 1991 addendum to the program plan. A major element will be the establishment of a Ceramic Manufacturability Center in the HTML. A first CRADA for joint work by industry, ORNL, and the Y-12 Site on ceramic machining was signed in March 1992.

A second project in Advanced Transportation Materials is Tribology, with the goal of understanding and reducing friction and wear of materials such as ceramics, carbon-based materials, and composites. Tests during the next year will be concentrated on carbon-graphite and silicon nitride.

Three additional projects in Advanced Materials are under consideration: Material Solutions for Alternative-Fueled Engines, Lightweight Materials for Automotive Applications, and Electrochemical Propulsion Materials. Needs assessments are under way in all three areas, with strong input from relevant industrial institutions. Draft multiyear plans are scheduled for completion early in FY 1993.

The HTML houses laboratories and special equipment to support the Office of Transportation Technologies, other DOE offices, universities, and industry in advanced materials research. Six user centers are operated within the HTML with funding designated for this purpose. At the end of 5 years of operation, in July 1992, we estimate that there will be agreements in place with 95 industrial institutions and 80 universities. A new activity in FY 1992 is the HTML Fellowship Program. Its mission is education and technology transfer, accomplished through use of graduate, postdoctoral, industrial, and university faculty fellowships. The activity emphasizes research conducted by the fellows in the HTML but also includes assignment of HTML research scientists in industrial laboratories. Two new user centers are scheduled for start up in FY 1994: Materials Environmental and Tribology.

For the Office of Alternative Fuels, ORNL provides technical support and R&D on the Alternative Fuels Utilization project. Tasks include work with industry on emissions, ignition, and combustion in heavy-duty alternative-fueled diesel engines.

There are two current ORNL projects for the Office of Propulsion Systems. The Vehicle Thermal Environmental Control project has the objective of identifying pollution-free space-conditioning systems that are at the same time cost-effective and energy conserving. The project will likely progress from systems evaluation to engineering development activities. The Automotive Propulsion Technology project complements our work on alternative fuels utilization by examining and testing concepts for advanced engines.

ORNL supports the Office of the Deputy Assistant Secretary for Transportation Technologies with analyses of motor vehicle data and energy use. The results are published in a biannual report, the *Transportation Data Book*. We also perform selected studies on energy policy issues as related to fuel economy and clean air considerations.

Funding for ongoing EE projects will remain relatively level in most areas with steady, moderate funding increases for the HTML user centers, ceramic manufacturability under the Ceramic Technology project, and Automotive Propulsion Technology. As noted previously, new projects in advanced materials and cooperative R&D with the automotive industry may result in large funding increases in future years.

EF—Technical and Financial Assistance

ORNL provides evaluation and technical support for a number of programs in the DOE Office of Technical and Financial Assistance. The major current effort is the evaluation of the Weatherization Assistance Program. Data are being collected and analyzed on a nationally representative sample of program participants and matched control groups. This evaluation will end in 1994.

Assessments are also under way on two information programs: the Conservation and Renewable Energy Inquiry and Referral Service and the National Appropriate Technology Assistance Service. During FY 1992 plans will be developed for evaluating the State Energy Conservation Program. ORNL is conducting an ongoing analysis of the process of innovation in the Energy-Related Inventions Program. Finally, ORNL supplies technical information for the International Energy Agency Center for Analysis and Dissemination of Demonstrated Energy Technologies and for the Weatherization Assistance Program.

Additional studies in these areas will likely be undertaken as the current work is completed.

EK—Utility Sector

In Integrated Resource Planning, the goal is to develop and disseminate improved methods that utilities, public utility commissions, and others can use to plan and acquire energy resources. Specific ORNL tasks include preparation of handbooks, development of an expert system on evaluation, review of utility programs, and analysis of planning issues. Funding will continue at the present level.

The District Heating, Cooling, and Cogeneration Program seeks to advance the application of these energy-efficient technologies in the United States. ORNL has undertaken several tasks in the program, including program planning, conducting workshops, and software development. FY 1993 will be the final year for the program.

KK04—Policy and Management—CRE

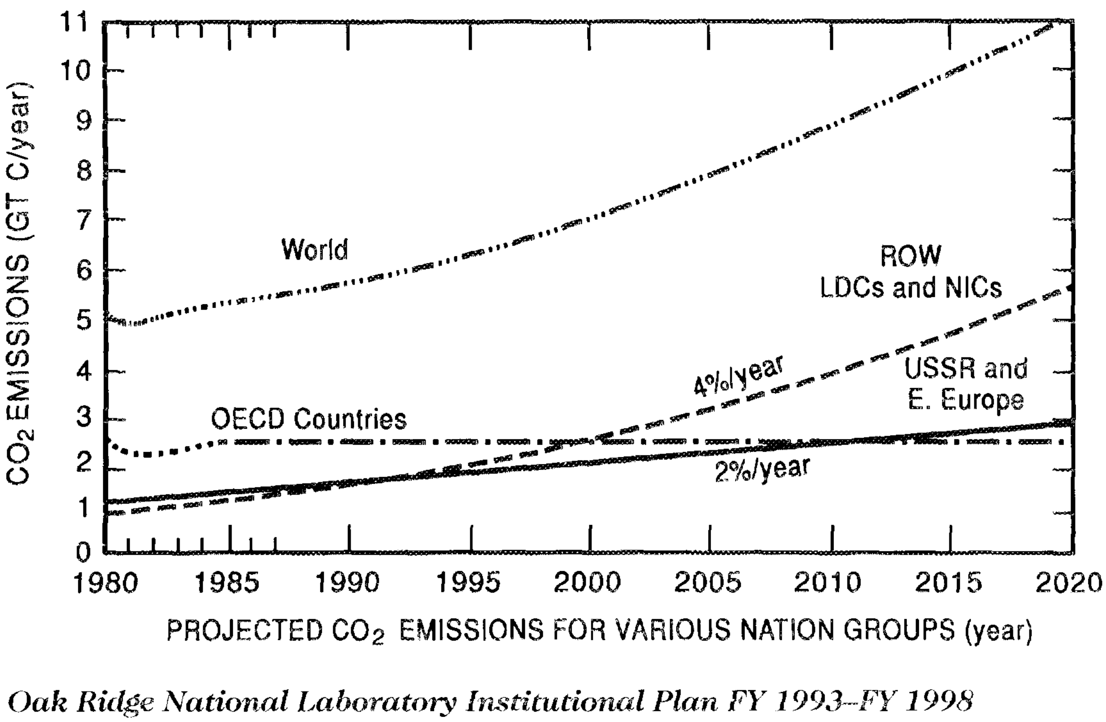
ORNL provides analytical support to the DOE/CE Office of Planning and Assessment in planning guidance, review and analysis of alternative strategies for achieving Conservation and Renewable Energy objectives, and management information system development and implementation.

Continuing Initiative

Better Energy Technologies for the Developing World

The energy choices made by developing nations (including those of Eastern Europe) will have growing environmental and economic ramifications for the United States. Clearly, as the economic gap between developing and industrialized nations narrows, an increasing share of the world's primary energy use will go to meet the needs of developing countries. This means at least three things to the United States: (1) Resulting energy use by developing nations (including fossil fuel consumption) is likely to contribute significantly to the global buildup of greenhouse and ozone-depleting gases in the atmosphere. (2) CO_2 emissions by developing nations (including China) may exceed those by industrialized nations in the first decade of the next century (Fig. 5.25). Energy use by developing

Figure 5.25
Projected CO_2 emissions for various nation groups shown are simple exponential extrapolations of the actual growth rates observed for 1977–1987. OECD—Organization for Economic Cooperation and Development; Eastern Europe and former Soviet Union, including Poland, East Germany, Czechoslovakia, Hungary, Romania, Yugoslavia, and Bulgaria; ROW—rest of the world, including China. The ROW includes all of the lesser developing countries (LDCs) as well as newly industrialized countries (NICs). Subtracting out the NICs delays the time when CO_2 emissions of LDCs cross those of the OECD countries by about 7 years.



nations is also likely to contribute to rising pressures on world oil markets. (3) Developing nations will be an expanding market for energy technologies during a time when the United States is trying to improve its competitiveness in the world economy.

Energy technology R&D can be an important part of the U.S. response to all three of these challenges. In particular, more energy-efficient technologies that are economical, biomass energy development, and improvements in environmental measurement and control capabilities will be needed. These technologies should be engineered to meet the particular circumstances of each developing country so that adoption rates can be maximized and the U.S. share of energy technology markets improved. DOE and other federal agencies have already begun to explore these opportunities. The interagency Committee on Renewable Energy Commerce and Trade (CORECT), chaired by a DOE official, is working to facilitate worldwide use of U.S. renewable energy and energy-efficiency technologies.

Since 1982 ORNL has been involved in energy technology and policy assessments in developing countries. These assessments have been supported largely by the U.S. Agency for International Development (AID), but support has come from DOE as well. This experience has extended to 21 countries in Asia, Africa, Latin America, and the Near East, and it has embraced fossil technologies, biomass and other renewable resources, and energy efficiency improvements. As a consequence, ORNL represents a unique combination of broad-based developing country experience; broad-based energy technology R&D expertise and facilities; and informed perspectives on such issues as global climate change, technology transfer, and public-private sector collaboration.

With this background, ORNL's role in what is emerging as a major national initiative will be focused on technology R&D, that is, ways to meet the energy needs for economic growth in developing countries while reducing stress on the global environment and world oil market—and improving the U.S. trade balance—through technology development, improvement, and adaptation.

The ORNL initiative in broad outline consists of four major activities. These are

- Nation- and region-specific R&D agendas. In consultation with DOE, ORNL will select a limited number of key nations or regions and, in close collaboration with sister R&D institutions in those areas, will assess needs for energy technology improvements or adaptations to meet their needs. Nations or regions will be selected on the basis of their importance (1) to global warming (e.g., the CIS, China, India, and Brazil); (2) as potential markets for U.S. energy technologies (e.g., Eastern Europe and Southeast Asia); and (3) in meeting development needs (e.g., the Sahel) or U.S. policy objectives (e.g., Eastern Europe and Central America). Based on the assessments, R&D agendas will be developed and pursued in cooperation with the U.S. private sector and indigenous counterparts. This step will be followed by efforts to encourage the demonstration and use of improved technologies and efforts to transfer the new options to other countries or areas.
- Selected technology-specific R&D agendas. In some cases ORNL is prepared to combine its developing country experience with DOE program priorities to identify energy technology R&D directions that are likely to meet the needs of a number of developing areas. Some candidate technologies include biomass production and conversion; heating, ventilation, and air conditioning (HVAC) equipment for buildings; environmental diagnostic and control systems; technologies for electricity distribution; and power electronics. In such cases R&D initiatives at ORNL will serve as catalysts for DOE programs and as sources of ideas for the U.S. private sector. For example, two promising opportunities are biomass plantations in China and gas-fired, ground-coupled heat pumps in the CIS. As external financial support grows, the Laboratory will involve the private sector as a full partner in the R&D process (much like ORNL has done in buildings energy conservation R&D).
- Support for foreign national and regional energy efficiency efforts. ORNL will continue to assist DOE in international programs that promote energy efficiency and expansion of trade opportunities for U.S. industries. These include CORECT, which increased its scope in FY 1991 to include a wider range of countries and energy-efficiency technologies, the Program to Support Eastern European Democracies, which has established centers in several East European countries to assist the transfer of American energy-efficiency technologies, and the Asian-Pacific Economic Council, which has established a U.S.-led subcommittee on energy efficiency.
- Comprehensive energy information system. ORNL will explore possible opportunities to create a comprehensive information system to collect and to disseminate information

about energy technologies, energy assistance activities in the developing countries, and options and purveyors of assistance for the developing countries. The lack of such an information system is a major gap in the current programs of assistance. ORNL's extensive experience with technical information centers should be a major asset as organizations work together to meet this need.

We anticipate sponsorship of the ORNL initiative from the following organizations:

- The DOE Office of Conservation and Renewable Energy (CE) is supporting ORNL's activities with the Center for the Analysis and Dissemination of Demonstrated Energy Technologies and with the Asian-Pacific Economic Council organization.
- Support from the AID Office of Energy and from AID mission and regional offices will continue for monitoring and evaluation activities for the Central American Rural Electrification Support project. In addition, a similar evaluation effort will begin for the AID-sponsored Petén Biosphere Reserve project in Guatemala.
- The EPA is pursuing opportunities to assist developing countries with environmental centers. These centers are likely to include energy-efficiency initiatives.
- The background paper for the National Energy Strategy suggests a major DOE role in energy technology R&D for developing countries. If a program is established to meet this need, it would become a significant sponsor of ORNL's efforts. Principal support is likely to come first from DOE's Office of Conservation and Renewable Energy, but, in time, support might also come from Nuclear Energy, Fossil Energy, and International Affairs.

A full national program for energy technology R&D for developing nations might require from $100 million to $200 million per year. Table 5.23 indicates the budget proposed for the ORNL initiative in this subject area. For FY 1992–FY 1996, about $1 million of the total in each year has been included in the projections for Program EF in the "Resource Projections" section.

Table 5.23
Combined DOE and Work-for-Others operations budget projections by fiscal year for Energy Technologies for Developing Nations Initiative[a]
($ in millions—BA)

	1993	1994	1995	1996	1997	1998
Non-DOE (AID)	0.8	1.0	1.0	1.0	1.0	1.0
DOE	1.2	3.0	7.0	8.0	9.0	9.0
Total	**2.0**	**4.0**	**8.0**	**9.0**	**10.0**	**10.0**

[a]Note that these figures are a subset of total financial support for ORNL work in developing countries and, in the case of Agency for International Development (AID), are less than the total resources projected from that agency in the near future.

Assistant Secretary for Fossil Energy

ORNL programs for the Assistant Secretary for Fossil Energy cover the following areas: coal, clean coal technology, support to the Strategic Petroleum Reserve, and support to the Naval Petroleum and Oil Shale reserves. The principal focus of ORNL's fossil-energy activities, however, is coal. The coal budget is anticipated to increase in FY 1992 primarily because of additional efforts in materials, chemical processing and bioprocessing of coal, and ES&H areas (Table 5.24).

AA—Coal

Materials research activities—including management with the DOE Oak Ridge Field Office (DOE-OR) of the Fossil Energy Advanced Research and Technology Development

Table 5.24

Assistant Secretary for Fossil Energy major program summary

($ in millions—BA)[a]

Budget and reporting code	Major program	FISCAL YEAR 1991	1992	1993	1994
AA	Coal	5.9	6.2	5.9	10.6
AC	Petroleum	0.1	0	0.1	0.1
AZ	Innovative Clean Coal Technology	0.5	0.4	0.6	0.7
SA	Strategic Petroleum Reserve	0.3	0.4	0.4	0.4
Total		**6.8**	**7.0**	**7.0**	**11.8**
Percentage of total Laboratory funding		1.3	1.2	0.8	1.1

[a]Figures include operating BA, capital equipment, and construction, if any.

Materials Program—comprise the major portion of the coal budget. In addition to ceramic composites and advanced alloy development, electrolyte systems, development of advanced coatings and claddings, inorganic membranes, and technology transfer have been integrated into the materials program.

Fiber-reinforced ceramic composites with improved strength and toughness are being produced by the forced chemical vapor infiltration and deposition process developed at ORNL. Ceramic composites have a variety of applications in fossil-energy systems such as high-temperature heat exchangers and hot-gas cleanup filters. Current work also emphasizes understanding the nature of the fiber-matrix interface with the aim of improving the mechanical properties of composites. Ceramic membranes for the separation of gases in high-temperature and hostile environments are being developed and tested. Other work is devoted to the microwave sintering of ceramics. This technology will be important in the fabrication of electrode and electrolyte materials with improved electrical properties for solid oxide fuel cells.

ORNL is developing advanced austenitic alloys for use in fluidized-bed and pulverized-coal combustion power plants. The objective of this work is to modify existing alloys that will satisfy the strength and corrosion-resistance requirements of high-temperature and high-pressure, second-generation power plants. Intermetallic alloys based on Fe_3Al are being developed for applications in which superior oxidation and sulfidation resistance and strength are required. Improved room-temperature ductility and resistance to hydrogen embrittlement will continue to be emphasized in the next several years. Current materials and designs for tubesheets and manifolds for hot-gas filter systems are being examined; the aim is to recommend a tubesheet material suitable for long-term operation of these systems.

New combustion work will focus on ceramics and high-temperature alloys as well as on the evaluation of chaotic components of fluidized-bed combustion.

Corrosion research at ORNL centers on studies of the formation and breakdown of protective oxide scales, particularly in sulfur-containing atmospheres and on the effect of environment on corrosion of iron aluminides.With the use of a special mechanical properties microprobe, an understanding of the properties of oxide scales is evolving.

ORNL has a commitment to transfer the technology developed in the Fossil Energy Materials Program to industry and to others in the fossil energy community. ORNL has three licenses to produce powder and wrought forms of iron aluminides, and a CRADA is under discussion. Another significant technology transfer effort is a CRADA with the 3M Company for the transfer to industry of a process for fabricating full-size ceramic composites utilizing technology developed at ORNL.

In the ES&H area, technical and analytical support is being provided to the Morgantown Energy Technology Center by evaluating environmental concerns related to coal research and development projects and by preparing NEPA assessments of the projects. Future work may involve performing field studies to collect environmental data for use in upcoming assessments.

R&D for coal processing at ORNL involves biological conversion to liquids and gases, biological beneficiation of coal and coal-derived liquids, and the evaluation of coal-derived liquids produced from mild gasification processes. Advanced bioreactor systems are being developed for coal processing, and the use of biological catalysts in nonaqueous media is being studied. It has now been shown that as much as 24% of some types of coal can be liquified/solubilized by modified enzymes in organic solvents in small fluidized-bed reactors, as is shown in Fig. 5.26.

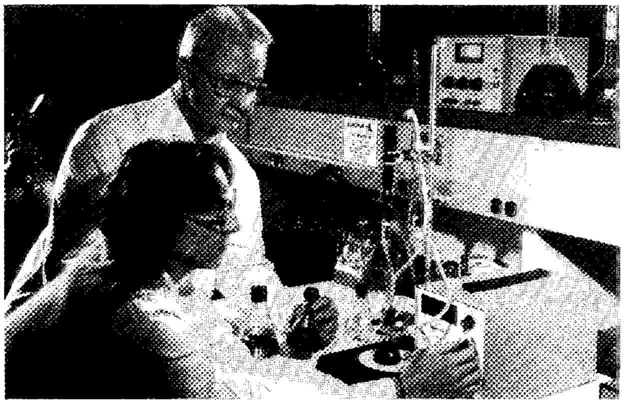


Figure 5.26 Modified enzymes in organic solvents are used to convert coal to liquids in a small fluidized-bed reactor.

AC—Petroleum

Technical and analytical support will be provided to DOE for the Oil Research Program. An important component of ORNL's involvement is the environmental support in preparing a programmatic NEPA assessment of the program. The goal of the Oil Research Program is to maximize the economic producibility of domestic oil resources by implementing a research, development, and demonstration plan in collaboration with state governments, industry, and academia.

AZ—Innovative Clean Coal Technology

Work on the Clean Coal Technology Program (CCTP) includes support in the areas of environment and materials. The CCTP is jointly funded by DOE and industrial organizations. Four solicitations have been completed by DOE, and a fifth solicitation for the CCTP is planned for future years. An important part of ORNL's involvement in the CCTP is environmental technical support to DOE in the preparation of NEPA assessments of site-specific projects. Materials failure analyses (critical to the success of clean coal technologies) continue to be conducted for the Pittsburgh Energy Technology Center. Work related to the CCTP is expected to remain at the present strong level of effort over the next 5 years.

SA—Strategic Petroleum Reserve

ORNL is performing work for the Strategic Petroleum Reserve Program with assistance to the Strategic Petroleum Reserve in the assessment of alternative methods of financing oil acquisition and in the development of models for planning the capacity and management of the SPR. SPR support activities are expected to remain level in the next 5 years.

Assistant Secretary for Environment, Safety, and Health

ORNL work for the Assistant Secretary for Environment, Safety, and Health includes development of environmental policy assessment methodologies and models;

application of these to analyze proposed and existing environmental legislation and regulations; development of environmental-compliance guidance; planning and assessment of technologies for dealing with radiological emergencies; participation on DOE Tiger Teams; and training of DOE and contractor staff in compliance with environmental laws and regulations. Table 5.25 presents summary budget information for this program area.

Table 5.25
Assistant Secretary for Environment, Safety, and Health major program summary
($ in millions—BA)[a]

Budget and reporting code	Major program	FISCAL YEAR 1991	1992	1993	1994
HA	Enviromental Research and Development	7.5	7.1	7.5	7.6
HR	Epidemiologic Activities	0.2	0	0	0
HS	Office of Security Evaluations	0.1	0.1	0.1	0.1
Total		**7.8**	**7.2**	**7.6**	**7.7**
Percentage of total Laboratory funding		1.4	1.2	0.9	0.7

[a]Figures include operating BA and capital equipment, if any.

HA01—Environmental Safety and Health

The Laboratory continues to provide technical support to all offices under the Deputy Assistant Secretary for the Environment. Activities include regulatory analysis, analysis of environmental impacts of energy development, technical input to policy analysis, technical guidance on compliance with environmental regulations, and training.

Environmental Guidance and Compliance • ORNL will continue to provide extensive technical support to the Office of Environmental Guidance. Long-standing work for this office encompasses a variety of regulatory activities including the tracking and analysis of regulations and the development and dissemination of regulatory information and guidance. In FY 1990 in response to Secretary Watkins' ten-point initiative for improving DOE's environmental performance record, ORNL provided substantial new support for training in environmental laws and regulations. The development and implementation of training courses in environmental regulation for DOE and DOE contractors will continue. ORNL also provides technical support to the Office of Environmental Guidance in matters concerning standards and procedures development, calculational model validations risk assessment, and radiation protection requirements. With regard to procedures development, ORNL currently is developing a radiological survey procedures manual, which provides detailed specifications for measurement and assessment of radiological environmental pollutants. The manual will serve as the basis for radiological surveys at DOE and contractor facilities. ORNL staff are also providing support to DOE's Risk-Based Standards Working Group, which is developing guidance on health and environmental risk assessments performed at DOE facilities.

NEPA Oversight • ORNL continues to provide technical support to the Office of NEPA Oversight. Technical support includes assistance with the development of guidance for compliance with NEPA, preparation of related background information, review of NEPA documents, and assistance at DOE-HQ. A major initiative related to the new DOE rule on the NEPA compliance (10 CFR 1021) is assistance with the revision of the Office of NEPA

Oversight's *NEPA Compliance Guide.* In FY 1993, ORNL has been tasked to develop audit protocols to assess compliance with NEPA at DOE facilities nationwide.

Environmental Audit • ORNL expertise in environmental and health risk analysis is available to help prioritize actions required to comply with environmental regulations, Federal Facility Agreements, and consent orders.

Safety Policy and Standards • ORNL has developed the capability for conducting large-scale hydrogeological and environmental characterization activities that are essential to addressing the contamination problems that occur on many of the DOE sites. An increasing interaction with regulatory agencies is creating the need for a uniform, efficient, and well-organized approach to development and initiation of site-wide characterization studies. ORNL will plan to serve as the coordinating center for characterization of selected DOE sites throughout the country—drawing heavily on the experience developed in work done on the Oak Ridge Reservation, which is hydrogeologically the most complex of any of the sites.

ORNL support to the Office of Environmental Audit in completion of their environmental survey terminated in FY 1990. ORNL technical support in site-prioritization efforts, environmental audits, and emergency-response R&D is available.

ORNL ES&HC Staff, supported by HASRD staff, have coordinated the initial DOE-wide Safety and Health Five-Year Planning Process for the Assistant Secretary for Environment, Safety and Health and now continue in coordinating the process refinement and functional implementations.

Neutron Dosimetry Using Bubble Technology • There is a need for improved neutron dosimetry at all DOE facilities. Development and utilization of superheated drop (bubble) technology is one of the most exciting and promising advances in neutron dosimetry in the past two decades. The Dosimetry Applications Research (DOSAR) group has combined the threshold detection features of bubble dosimeters with traditional board response of thermoluminescent albedo dosimeters to develop a Combination Area Neutron Spectrometer (CANS) and a Personnel Neutron Dosimeter/Spectrometer (PENDOS). Because the resulting unfolding analysis techniques are simple, this combination rapidly yields the neutron dose as well as the neutron energy spectrum. As these are developed and the technology is transferred to industry, they should form the core of a new generation of small, accurate, low-cost neutron personnel dosimeters and spectrometers.

Nuclear Accident Dosimetry Performance Test Program • DOE facilities with the potential for a nuclear criticality accident are required to have nuclear accident dosimetry capabilities and to ensure that they will function properly. Annual Nuclear Accident Dosimetry Intercomparison Studies conducted at the Health Physics Research Reactor (HPRR) met training, educational, and performance testing needs until the shutdown of the HPRR in 1987. Since then, no such testing and training have occurred. The DOSAR group is attempting to organize a Nuclear Accident Dosimetry Applications Test Program using the fast pulse reactor at the Army Pulse Radiation Facility in Aberdeen, Maryland. The proposed program is essential to provide for the proper testing, education, and training throughout DOE.

Continuing Initiative

Center for Risk Management

The Center for Risk Management is housed in the Health and Safety Research Division. A major mission of this center is to focus the Laboratory's resources even more strongly on evaluating risks to human health and on prioritizing and solving environmental problems related to energy production and consumption. Environmental restoration is a principal concern; however, many health and environmental problems of major national or international significance fall within the scope of the center. Other examples of current interest include radionuclides and toxic chemicals, acid deposition, and climate change as well as policy and management mechanisms to reduce their adverse impacts.

The center will draw on the expertise of basic researchers within the ORNL divisions and will emphasize the integration of science into decision making. Examples of activities to be actively pursued by the center include environmental fate/transport modeling, human and environmental toxicology, epidemiology, applied ecology, environmental monitoring, data base development, risk/benefit, and policy analysis. In addition to developing methods and performing assessments, the center will provide technical assistance to sponsors responsible for performing or interpreting risk assessments and for managing societal risks.

The Center for Risk Management will (1) increase communication among scientists working in different divisions and programs; (2) ensure that risk assessments and analyses performed for all sponsors meet the highest possible standards of technical excellence; (3) provide a common focus for marketing a Laboratory-level initiative in risk assessment, analysis, and management; (4) ensure the prior application of technical, social, and political input into our assessments; (5) promote training and educational initiatives aimed at professionals in the field and the public; and (6) establish Martin Marietta Energy Systems, Inc., as a national leader in this very important risk assessment area. The staff of the four environmental, life, and social sciences divisions are among the world's leaders in applying the concept of risk assessment to today's critical environmental problems. The establishment of this center will significantly enhance outside recognition of ORNL's leadership in this field. Table 5.26 lists budget projections for the Center for Risk Management.

Table 5.26
Budget projections by fiscal year for the Center for Risk Management[a]
($ in millions—BA)

	1993	1994	1995	1996	1997	1998
Operating expense	12.0	20.0	20.0	20.0	20.0	20.0

[a]Funding is being sought from the Assistant Secretary for Environment, Safety, and Health under Program HA, Environmental Research and Development, the Assistant Secretary for Environmental Restoration and Waste Management under Program EM, and from other sources.

Continuing Initiative

Health Physics Instrumentation Center of Excellence

Recent attention to ES&H issues has revealed that an acute national need currently exists for improved health physics radiation monitoring instrumentation and radiation calibration facilities. Designed to meet this need, this new initiative involves cooperation throughout Energy Systems and the organization and development of a center known as Associated Laboratories for Excellence in Radiation Technology (ALERT).

The purpose for ALERT centers on instruments, detectors, and other devices used for radiation measurements in health physics programs. It will emphasize R&D related to such devices, an area that has been severely neglected in recent years. Other central functions of ALERT will be calibration and performance testing of various health physics devices. This will, as a matter of course, also involve evaluation, maintenance, and quality assurance testing activities. The sharing of research advances, calibration information, and performance testing information with the scientific and technical community by technology transfer activities will be an integral part of ALERT.

The management of ALERT will be centered in the HASRD at ORNL because of the emphasis on health physics R&D activities. In addition to HASRD researchers, health physics instrumentation experts from the Instrumentation and Controls Division will function as a vital part of the research team. The combined radiation calibration facilities of Energy Systems will form the nucleus of the experimental portion of ALERT. Specifically, ALERT will make available the Radiation Standards and Calibration Laboratory in the Office of Environmental and Health Protection at ORNL, HASRD's Radiation Calibration Laboratory, the Radiation Calibration Laboratory at Portsmouth Gaseous Diffusion Plant, and miscellaneous radiation sources and facilities at Paducah Gaseous Diffusion Plant, the Y-12 Plant, and the ORNL site. Instrument maintenance and testing functions will also be shared among the various Energy Systems plants; the major work is expected to be performed at ORNL and Portsmouth Gaseous Diffusion Plant.

ALERT is expected to become certified by NIST as a Secondary Standards Calibration Facility for Ionizing Radiation and also to become a national test facility for health physics instrumentation performance. In summary, ALERT is expected to meet Energy Systems calibration needs, the R&D needs of the health physics community, and national needs associated with performance test programs and NIST standards activities. Table 5.27 presents a summary of budget projections for this initiative.

Table 5.27

Budget projections by fiscal year for the Health Physics Instrumentation Center for Excellence Initiative[a]

($ in millions—BA)

	1993	1994	1995	1996	1997	1998
Total funding	1.9	2.1	1.7	1.7	1.6	1.6

[a]Funding is being sought from the Assistant Secretary for Environment, Safety, and Health under Program HA, Environmental Research and Development.

HR—Epidemiologic Activities

ORNL provides technical support to epidemiological activities conducted for the Assistant Secretary for Environment, Safety, and Health. Under HR01 05, support regarding ES&H is provided in the area of conducting epidemiologic research activities, including the Radiation Effects Research Foundation. Under HR01 35, support is provided to K-25 Site worker safety studies. The HR-funded activities at ORNL were previously funded through Biological and Environmental Research in OHER and other DOE offices.

HS—Office of Security Evaluations

ORNL provides support to various activities associated with the development and maintenance of state-of-the-art analytical methods used in the review of safety analysis reports for packagings. These methods include computer codes and other advanced assessment tools.

Office of Civilian Radioactive Waste Management

ORNL's work for the DOE Office of Civilian Radioactive Waste Management (OCRWM) is conducted under Program DB. ORNL's DB activities currently involve the geologic repository (DB01), transport and systems engineering (DB04), and program management and technical support (DB05). The work is declining in scope during FY 1992 as the new OCRWM management and operating (M&O) contractor transitions into these activities. Beginning in FY 1993, it is expected that very little of the DB activities will remain at ORNL. Table 5.28 shows the OCRWM budget summary as developed using projected funding for FY 1993 and beyond.

Table 5.28

Office of Civilian Radioactive Waste Management major program summary

($ in millions—BA)[a]

Budget and reporting code	Major program	FISCAL YEAR 1991	1992	1993	1994
DB	Nuclear Waste Fund	8.6	0.5	1.6	1.2
Percentage of total Laboratory funding		1.6	<0.1	0.2	0.2

[a]Figures include operating BA, capital equipment, and construction, if any.

DB—Nuclear Waste Fund

The repository component of the OCRWM Program, which supports the ongoing geotechnical activities in support of the Yucca Mountain Project, was significantly reduced after FY 1989; further reductions occurred in FY 1990 and FY 1991. Activities in this area, which are generally funded at a low level, may continue beyond FY 1992.

The transportation and systems engineering component of the program supports two activities at ORNL. The first, Transportation Operations Project Office (TOPO), provides support to the Transportation Branch at OCRWM. TOPO's current work focuses on technical support for institutional activities, transportation economic and systems analyses, transportation operations/support systems development, and transportation program management. Significant activities include the development of an assessment of trends in the rail industry; developing a strategy for emergency response; assessing the capabilities of facilities to accept casks transported by different modes; developing, documenting, and maintaining the ability to project transportation routes; continuing the development of site-specific services planning documents, which are the first step in ensuring proper operational interfacing of the transportation system with facilities; assisting the OCRWM M&O contractor in assessing the impacts of delivery commitment schedules as they are submitted by utilities to DOE; completing the development of a transportation system description and a functional analysis; supporting DOE in its observations of ongoing spent nuclear fuel cask handling activities; assessing feasible startup rates for the OCRWM Transportation System; defining contingencies for starting up transportation using existing systems; and completing assessments of issues related to the standard disposal contract. All transportation-related activities at ORNL are projected to terminate at the end of FY 1992.

The second activity, the systems-engineering component, is embodied in completing the verification and documentation of the waste stream analysis capability; issuing the second revision of the Waste Characteristics Data Base; initiating the improved applications for the ORIGEN2 code used for projecting radionuclide inventories; and modeling the impacts of discrete events on the operations of OCRWM facilities. These activities support OCRWM's ability to perform design and trade-off studies for establishing an integrated and efficient high-level nuclear waste management system. Some of these activities may continue at ORNL beyond FY 1992, specifically in finishing the improved applications of ORIGEN2 and possibly some technical support in the characteristics data base area.

The technical support area includes a jointly funded activity where the Integrated Data Base is maintained, providing a comprehensive, top-level perspective on the wastes that must be handled by DOE in the future. The Integrated Data Base contains DOE's official spent fuel and radioactive waste inventories and projections through 2020. This is an area where support is expected to remain stable beyond FY 1992.

Assistant Secretary for Environmental Restoration and Waste Management

ORNL programs for the Office of Environmental Restoration and Waste Management (EM) are primarily in the areas of environmental restoration, waste management, technology development, and quality assurance/quality control. ORNL receives funding in all of these categories, with the bulk of the funding being supplied through the Energy Systems central organization in FY 1992 and beyond (see Table 5.29).

Table 5.29
Office of Environmental Restoration and Waste Management major program summary
($ in millions—BA)[a]

Budget and reporting code	Major program	FISCAL YEAR 1991	1992	1993	1994
EW	Environmental Restoration and Waste Management—Defense	9.3	4.5	0	0
EX	Environmental Restoration and Waste Management—Nondefense	5.7	13.0	0	0
	Landlord	9.1	7.7[b]	7.0	
Subtotal		**24.1**	**25.2**	**7.0**	**0**
	DOE funding from Energy Systems Central Organizations				
EW	Environmental Restoration and Waste Management—Defense	43.0	95.9	128.7	117.5
EX	Environmental Restoration and Waste Management—Nondefense	21.2	20.5	90.6	121.4
Subtotal		**64.2**	**116.4**	**219.3**	**238.9**
Total		**88.3**	**141.6**	**226.3**	**238.9**
Percentage of total Laboratory funding		16.3	23.3	25.6	22.8

[a]Figures include operating BA, capital equipment, and construction.
[b]Includes funding for general field-work proposals for Occupational Safety and Health Administration and other safety activities.

Environmental Restoration

An integral part of the Environmental Restoration (ER) Program is the Facility D&D. Functions cover surveillance and maintenance (S&M) of surplus radioactively contaminated facilities and D&D of the contaminated facilities. S&M and D&D activities are funded directly by Energy Systems ER Division. (See "Environmental Restoration and Waste Management Activities" in Sect. 6.)

The Isotope Facility Shutdown Program began as a result of significant descoping of the Isotope Production and Distribution Program at ORNL, leaving numerous production facilities to be shut down. Included in this task is the preparation of an ORNL facilities shutdown plan, which outlines activities, costs, and schedules for modifying the facilities and associated documentation to allow acceptance into the Surplus Facilities Management Program (SFMP). This task implements the shutdown plan, which includes facilities surveillance, inventory reduction, executing facility modifications, and preparation of appropriate documentation to support all activities to allow acceptance by the SFMP.

Major activities in remedial action programs (RAPs) involve conducting radiological surveys on private properties near inactive mill tailings sites [Uranium Mill Tailings Remedial Action Project (UMTRAP)] and at facilities formerly used under contract with the Atomic Energy Commission [Formerly Utilized Sites Remedial Action Project (FUSRAP)]. Identification, characterization, and verification of the current radiological status of sites involved in DOE's RAPs are performed to provide a basis for the reduction of health impacts of fuel-cycle activities. To perform its activities in a cost-effective manner, ORNL maintains an office in Grand Junction, Colorado, at the request of DOE. Advancement of state-of-the-art equipment and methodologies is an integral part of this work. The ORNL Grand Junction facility is leading the effort in identifying and recommending inclusion of various properties in the vicinity of 24 inactive uranium mill sites in UMTRAP. Additionally, the Grand Junction facility is responsible for verifying the adequacy of remedial action taken at those sites in excess of relevant EPA criteria and DOE guidelines in UMTRAP and the western sites in SFMP. ORNL survey efforts were reduced sharply in UMTRAP in FY 1991 because of completion of most of the inclusion surveys.

The Oak Ridge ORNL-based group, which has functions equivalent to those of the ORNL group at the Grand Junction facility, performs identification, designation, and verification activities at the radiologically contaminated sites in the FUSRAP and eastern SFMP sites. FUSRAP funding is expected to remain level through 1995. SFMP funding, on the other hand, is expected to increase significantly as the amount of decommissioning efforts at federal facilities increases. The SFMP and the Defense Decontamination and Decommissioning projects provide (1) maintenance and surveillance to ensure the safety of DOE facilities awaiting decommissioning, (2) planning for the orderly decommissioning of facilities, and (3) implementation of a program to accomplish disposition of all facilities. ORNL will provide verification that these facilities are decontaminated within established DOE guidelines.

If DOE wishes to decontaminate its formerly used buildings and to release them for unrestricted use, there will be a need for well-documented clearance criteria. One necessary aspect of those needed criteria is definition of the relationship between residual surface contamination and absorbed dose resulting from skin absorption, ingestion, or inhalation of dusts or vapors arising from the surfaces. Staff from HASRD have expertise in the areas of radiological surveying and indoor air quality. These capabilities are being used to make measurements and to refine models that can be used for this purpose.

The Energy Systems Groundwater Program Office (GWPO) was established in 1991 to promote consistency among groundwater activities at the five DOE facilities operated by Energy Systems and to act as a focal point for technical and programmatic interactions with the public and state and federal regulatory organizations. It functions through a program manager and five groundwater protection program coordinators. Each coordinator is responsible for oversight of all groundwater activities at their facility and for facilitating integration of requirements of the compliance and environmental restoration groundwater programs. The Oak Ridge Hydrology Support Program provides technical support to the GWPO and the coordinators to assist in gaining technical consistency and defensibility across all the site programs and to facilitate sharing of lessons learned. This effort is expected to grow in 1993 to include at least one technical support staff member for each of the five sites, enhanced support for data management, and expanded work in groundwater modeling, which will also draw upon new supercomputer capabilities coming to ORNL.

Waste Management

The mission of Waste Management (WM) is to fully manage wastes for the purpose of protecting human health and safety and the environment. While implementing this mission, ORNL must minimize future generation of wastes, and WM operations must be conducted in a technically sound, economical, publicly acceptable, compliant, and safe manner. This mission is carried out through comprehensive planning; coordination of waste reduction; upgrading or construction of new facilities; and collection, treatment, storage, certification, and disposal of wastes. Radioactive (low-level as well as transuranic), hazardous, mixed radioactive and hazardous, medical/infectious, and solid sanitary/industrial wastes are managed. Waste forms include gases, liquids, sludges, and solids. WM operates 34 facilities at the Laboratory and provides ongoing operations and upgrades of ORNL WM facilities needed to support the programmatic missions of DOE. Additionally, it manages wastes produced by pioneering radiochemical operations and research that supported the early mission of Defense Programs and its DOE predecessors. (See "Environmental Restoration and Waste Management Activities" in Sect. 6.)

Technology Development

The DOE Office of Technology Development (OTD) is charged with developing and demonstrating new technologies for dealing with DOE's environmental restoration and waste management problems (Fig. 5.27). At Energy Systems, the Office of Waste R&D Programs manages a diverse OTD program to address DOE's environmental and waste management problems. The program involves (1) developing new technologies as well as demonstrating or modifying existing techniques to ensure application of the most cost-effective and technologically advanced remediation and waste management methods and (2) developing energy-efficient waste-minimization technologies. This work is currently being conducted at ORNL, the Y-12 Plant, and the K-25 Site. The technologies being developed are shared among the DOE sites and with the private sector for use in solving similar environmental problems.

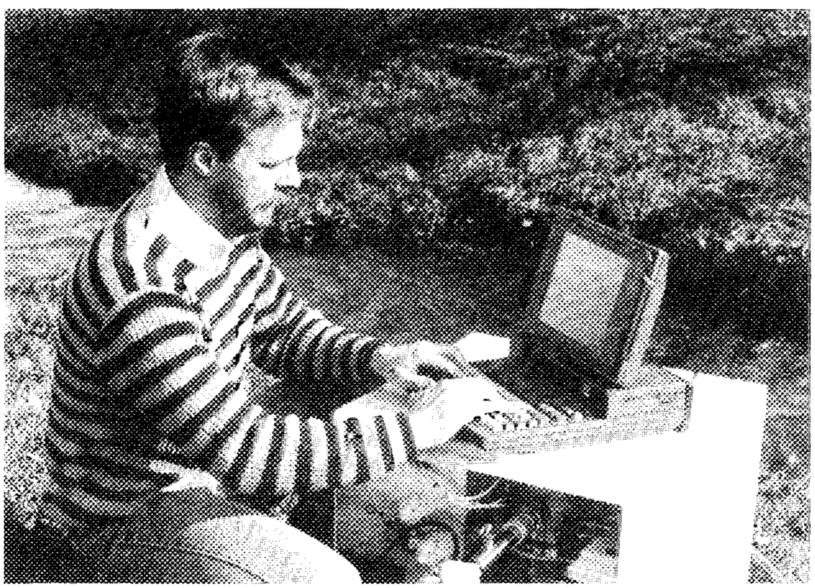


Figure 5.27 Cyril Thompson, Analytical Chemistry Division, demonstrates a transportable ion trap mass spectrometer, an instrument designed to provide rapid, less expensive, real-time analysis of volatile organic chemicals in soil, air, or water.

This multifaceted program can be partitioned into eight components, each of which is defined as follows:

- Transportation—data base evaluations and site verifications to develop an understanding of site-specific needs; systems engineering to evaluate methods of achieving transportation requirements for a reasonable number of applications, including hazardous and mixed waste remediation efforts; risk assessment and regulatory support to define the requirements systematically for on-site and off-site transport of hazardous and mixed waste; and base technology development to evaluate the effect of hazardous substances on packaging components.

- Bioremediation—microorganisms that can fix, degrade, detoxify, or accumulate select organic species (tetrachloroethylene, trichloroethylene, or PCBs) and inorganic species (uranium, strontium, cesium, lead, cadmium, or copper) in situ or in process.
- Characterization—modeling of hydrologic systems; advanced field measurement and sensing methods; improved systems for data collection, analysis, management, and display; instrumentation to monitor contaminant behavior and response to remediation strategies using improved, less costly, analytical means in situ and in real time; and field-oriented methods that allow both site and contaminant characterization with minimal cost, health, and safety impact.
- D&D—decontamination and decommissioning of metals and concrete to assist in the decommissioning of formerly utilized facilities and in the replacement of several major facilities in the Defense Programs Reconfiguration.
- Technology Transfer—facilitates the transfer of technologies that could potentially improve program and operational effectiveness, reduce costs, and save time among federal agencies, industry, academia, and the international community.
- Robotics—robotic systems and remote technology that can enhance environmental restoration and waste management operations by removing workers from radioactive, hazardous, and mixed waste, increasing speed and productivity of characterization and remediation, and reducing life-cycle costs.
- Treatability—inorganic membrane technology for in situ remediation of chromic acids, heavy metals, volatile and other organics in landfills; in situ immobilization, thermal treatment and/or advanced oxidation for the treatment of soils contaminated with volatile organic compounds and low levels of radioactive substances; and in situ vitrification to destroy instantly many hazardous components and to immobilize the remainder in a glass or slag matrix.
- Waste minimization—action that minimizes the volume or toxicity of waste by recycling, recovery and reuse of materials, source substitution, and process modification to reduce the production of radioactive, hazardous, and mixed wastes at the generation point.

Although these technologies are, to some extent, currently developed, much more refinement and advancement are necessary to allow them to be cost-effective for the increasingly more challenging waste problems. Significant industrial involvement is expected, especially during the demonstration phase of the technologies; this will require an efficient transfer of new technologies for application both to and from the DOE facilities.

In an effort to increase the number of qualified scientists and engineers, this program sponsors joint research projects with universities and minority institutions to encourage students to study in fields applicable to environmental restoration and waste management.

Significant recent accomplishments include the pilot scale demonstration of in situ vitrification of a trench containing radioactive materials; demonstration of direct sampling ion trap mass spectrometry (real-time measurements of trichloroethylene and perchloroethylene) at the Savannah River Integrated Demonstration Site; remote site characterization using a U.S. Army Soldier Robot Interface Project test bed; and remote surface mapping of waste in Fernald silos. Also, a CRADA with the General Electric Company was established to share funding and research results in the area of bioremediation of PCBs.

Quality Assurance and Quality Control

The Environmental Compliance Division (EM-22) in the EM Office of Quality Assurance and Quality Control (EM-20) at DOE headquarters is responsible for developing and coordinating written guidance to assist EM-wide program offices in implementing DOE policies and standards regarding federal, state, and local environmental requirements pertaining to the treatment, storage, and disposal of waste; corrective actions; and cleanup of inactive facilities and sites; determining the need for and implementing appropriate EM-wide training in specific technical and policy-related areas; providing independent review of environmental compliance documents [including NEPA documents, primary Comprehensive Response, Compensation, and Liability Act (CERCLA) documents, and documents prepared in response to Resource Conservation and Recovery Act (RCRA) compliance agreements and consent orders] developed for EM activities; and providing independent oversight and appraisal of environmental compliance within EM. The ORNL ESD has acquired extensive technical expertise in these areas and will assist EM-22 in its EM-wide document review, guidance, training, and auditing functions. A high-priority activity in this area is development of guidance for efficiently integrating CERCLA, NEPA, and RCRA documentation and requirements for EM activities.

Isotopes Facilities Shutdown Program

On December 11, 1989, DOE directed DOE-OR to prepare the ORNL isotopes production and distribution facilities for safe shutdown. The Isotopes Facilities Shutdown Program was created to manage the activities required to place the facilities in a radiologically and industrially safe condition such that they could be accepted into DOE's Environmental Restoration Program. ORNL prepared and DOE approved a plan that identifies the activities and funding requirements to accomplish the program objectives.[2]

The goal of the program is, by the end of FY 1994, to place all 17 facilities in the program in a condition such that (1) all stored radioactive materials, high-level wastes, and contaminated liquid waste have been removed; (2) the structures and radiation-monitoring systems are in a physical condition adequate to contain and to monitor any radioactive contamination in accordance with DOE Order 5480.1; (3) security systems and procedures are adequate to prevent unauthorized entry; and(4) all hazardous chemicals have been removed.

This program was initially funded through DOE's Office of Environmental Restoration and Waste Management (EM) and is managed by Nuclear Energy (NE). The program budget was $9.1 million in FY 1991, and $9.6 million in FY 1992. The budget estimates for FY 1993 and 1994 are in the range of $20 million to $25 million for each year. The level and source of funding for FY 1993 and FY 1994 are uncertain at this time.

Major accomplishments in FY 1992 include (1) completion of an environmental assessment of all planned shutdown activities, (2) a detailed review and cost estimate of all shutdown tasks, and (3) consolidation of all surplus radioisotopes into one Isotope Facilities Shutdown Program facility.

EX-70—West Valley Transfer Cart Control System

This proposal is for a memorandum of understanding only; West Valley Nuclear Services (WVNS) will be submitting the total formal budget request. This work supports the West Valley Demonstration Project Vitrification Facility, which is a DOE-funded facility to demonstrate the solidification of high-level radioactive waste.

ORNL is providing engineering assistance to WVNS on the control system for the Vitrification Facility Transfer Cart Project. Specifically, ORNL's effort includes controls, signal transmission, and electrical equipment related to the Transfer Cart. ORNL has previously developed similar technology for (1) radiation-hardened, wireless signal transmission in metal-lined facilities and (2) remotely controlled, battery-operated vehicles in remote environments. The engineering activities proposed to be performed by ORNL for WVNS are broken into three phases: Title I Design (completed), Title II Design, and Title II Engineering Support.

Energy Information Administration

The purpose of this program work is to provide the Energy Information Administration (EIA) a coordinated approach and a center of responsibility at ORNL by which EIA's objectives and technical needs may be met (Table 5.30).

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[2]*ORNL Isotopes Facilities Shutdown Program Plan*, ORNL/TM-11689, Martin Marietta Energy Systems, Oak Ridge Natl. Lab., October 1990.

Table 5.30
National Energy Information System major program summary
($ in millions—BA)[a]

Budget and reporting code	Major program	FISCAL YEAR 1991	1992	1993	1994
TA	Collection, Production, and Analysis	0.9	0.8	0.8	0.9
Percentage of total Laboratory funding		0.2	0.1	0.1	0.1

[a]Figures include operating BA and capital equipment, if any.

ORNL proposes to continue supporting EIA through (1) economic analysis in support of issue analysis and in support of EIA's ongoing energy-modeling activity; (2) analysis and evaluation of EIA's quality assurance activities, particularly through expert reviews; and (3) technical analyses including engineering studies. In addition, ORNL will apprise EIA of newly developing areas of expertise:

- energy-environmental economic modeling,
- information systems development,
- creative file structures and maintenance,
- artificial intelligence and expert systems,
- the development of an international energy data base through the ORNL–AID Program, and
- a growing number of analyses of technological change.

Funding for future years is expected to be stable in real dollars.

Federal Energy Regulatory Commission

Final environmental assessments were completed by ORNL researchers on the potential for cumulative impacts associated with the hydroelectric development in the Skagit River Basin and in the Nooksack River Basin. Future work will include EISs for each of the two river basins and several site-specific environmental assessments for selected hydroelectric projects in California and Colorado.

Other DOE Programs and Installations

ORNL continues to provide support to other DOE offices and installations, including the Assistant Secretary for Management and Administration; the Office of Policy, Planning, and Analysis; other DOE contractors and operational offices; and other Energy Systems sites. (Table 5.31).

Office of Administration and Human Resource Management

ORNL is conducting energy management studies in Laboratory facilities to identify retrofit projects to achieve the energy-consumption and efficiency goals established by DOE and reflected in ORNL's 10-year energy management plan. The following tasks are included: Chilled-Water Free Cooling Project; HVAC control system; Building 4500-S Project; proposed HVAC Control Projects for Buildings 4500-N, 4501/4505, 4508, 5500, and 3500; and studies to improve lighting efficiency and HVAC controls in ORNL facilities.

Table 5.31
Other DOE programs and installations
($ in millions—BA)[a]

	FISCAL YEAR			
	1991	1992	1993	1994
Office of Administration and Human Resource Management	1.4	0.1	0.2	0.2
Office of Policy, Planning, and Analysis	2.1	2.5	2.4	2.7
Federal Energy Regulatory Commission	0.6	2.1	2.4	1.6
Assistant Secretary for International Affairs and Energy Emergencies	0.1	0.1	0.3	0.3
DOE contractors and operations offices	22.6	21.2	32.7	31.3

[a]Figures include operating BA, capital equipment, and construction, if any.

WB—In-House Energy Management • ORNL has developed a comprehensive Energy Management Program to achieve goals established in its 10-year energy management plan. This program is comprised of 11 elements that collectively contribute to the achievement of the energy conservation goals. These elements integrate energy conservation activities specific to the Laboratory's buildings, processes, vehicles, and equipment. For example, retrofit projects include projects identified through completed surveys and studies that improve building and process operation energy efficiency.

To administer the energy conservation effort, ORNL has established an in-house Energy Management Steering Committee that includes senior-level management.

Currently, several studies are ongoing at ORNL. Through these studies an evaluation will be made to determine if any energy conservation retrofit projects can be economically justified. Six retrofit projects have been identified from recent studies and are now funded. These projects will upgrade the inefficient HVAC control system in several buildings and provide a centralized computer-based utility-metering system as well as a chilled water free-cooling heat exchanger for the central chilled water system.

WG—Strategic Facilities Utilization Program • The Strategic Facilities Utilization Program (SFUP) is a DOE-sponsored program to upgrade or demolish abandoned and unusable facilities. Since SFUP's inception in FY 1987, ORNL has completed several demolitions, with eight additional projects awaiting NEPA approvals. All SFUP work is not demolition. One project relocated a prefab bus stop, and a current project is restoring the Bethel Valley Church for use as a historical landmark in ORNL's 50th year celebration. The SFUP ended in FY 1991, but the program closeout has been extended into FY 1992–1993 to complete documentation and testing. The end of SFUP has left the Laboratory with a large number of potential projects that were identified from SFUP. These structures and facilities now head up our continuing strategic facilities list.

Office of Domestic and International Policy

Work for the Office of Domestic and International Policy (EP) will include research on transportation, energy efficiency, infrastructure costs associated with alternative fuels, alternative fuels supply issues and effects on energy security, consumer choice and demand issues for alternative fuels, and automobile and light-truck fuel-economy standards. Research will continue on the effects of clean fuels and reformulated gasoline on the energy industry, consumers, and the environment. ORNL will also perform research and analyses in support of EP's role in developing the National Energy

Strategy. ORNL anticipates continuing work in support of EP's support role to the Council on Environmental Quality in the development of a national strategy and plan for reporting long-term environmental trends. Additional support is provided in the area of regulatory analyses for hydropower development and environmental compliance issues.

For 17 years ORNL has supported the DOE Office of Environmental Analysis (OEA) in the development of energy resource assessment models and in the provision of background research for various energy and environmental policy issues. This support will continue with increased attention to environmental analyses in support of the National Energy Strategy process. The OEA is funding a variety of projects including a flue-gas desulfurization information system, development of a residual generating model for the National Energy Modeling System, analysis papers to support OEA's role in the National Energy Strategy process, studies of international developments in global climate change, a study of the relationships between automotive fuel economy and hydrocarbon emissions, research on estimating the physical and ecological effects of climate change, research on the economic valuation of energy-related environmental impacts, and studies of the impacts of environmental policies on electric utilities. A major effort is in progress to analyze fuel cycles and to provide estimates of (1) the physical impacts on environmental resources, including human health and safety and (2) costs and resulting potential effects on market prices for major fuels.

ORNL also provides support to the Office of Electricity/Coal/Nuclear/Renewable Policy on hydropower issues. In FY 1992 a feasibility study was completed on a hydropower environmental mitigation information analysis system. If DOE decides to continue support for this concept, additional, long-term funding may be received.

Other DOE Organizations

ORNL performs numerous small tasks, frequently on an ad hoc basis, for a number of other organizations within DOE, including the Assistant Secretary for International Affairs and Energy Emergencies, the Economic Regulatory Administration, the Federal Energy Regulatory Commission, DOE-OR, and others. These activities are distributed among the various Laboratory programs and together make up about 5% of the total Laboratory funding.

A program began in FY 1989 for the Office of Operational Safety, Transportation, and Facility Safety Division. This task provides evaluations, reviews, technical analyses, and development support in transportation areas related to hazardous materials, including regulatory compliance evaluations and appraisals; evaluation of exemption applications; safety analysis reports; proposed regulations, standards, and orders; formulation of safety-related requirements; and preparation of supporting documentation. The program includes support for the actual performance of compliance appraisals, safety-related program evaluations, and evaluation of regulatory-related activities. This program is expected to experience moderate growth through FY 1991 and then remain stable.

For the past several years, ORNL's Energy Division has conducted state-of-the-art program evaluation research for Bonneville Power Administration's Office of Energy Resources. This research has focused primarily on the performance of residential energy retrofit programs. Bonneville has operated a Residential Weatherization Program since 1981. ORNL's evaluation research has centered on the energy saved by this program over time. Recent research has expanded into issues concerning the energy efficiency of new residential buildings, compliance with Bonneville's Model Conservation Standards, the fuel choices of customers, and integrated resource planning. The Energy Division will also extend its leadership in the fields of artificial intelligence and power systems by developing a system to monitor Bonneville's substation equipment in real time to support reliability-centered maintenance.

Staff from the HASRD have many ongoing projects involving the development or demonstration of field-portable techniques for detecting organic chemical components at or near hazardous waste sites. Derivative ultraviolet absorption spectroscopy using fiber-optic cables has been demonstrated to detect benzene, gasoline, and other contaminants in groundwater with a very rapid response (<1 min) using rugged, lightweight instruments. Spectrochemical techniques are expected to be equally successful in the detection of trace amounts of chlorinated hydrocarbons in soil and groundwater. Underground storage tanks could be safely evaluated by robotic controls as laser light is directed via optic cables into the tank interior. The Raman spectroscopic response from the layered materials in the tank could be directed back up the same cable to the operator, allowing the tank to be assessed with minimal change of human exposure to potentially carcinogenic, toxic, or radioactive compounds.

DOE's Office of Arms Control is supporting efforts to develop rapid, portable methods for detection of airborne chemical agents. Staff in the HASRD have been applying the technique of surface-enhanced Raman spectroscopy to this problem. Laboratory work has revealed the technique to be both rapid and sensitive. Field tests will be needed to see if there is sufficient selectivity under real world conditions.

Other Energy Systems Sites

Y-12 Plant managers continue to need new or better field screening tools in the assessment of environmental restoration needs at the plant. Staff from HASRD field-test newly developed analytical techniques at Y-12 sites. In addition, they provide Y-12 with a rapid-response, field-portable, analytical capability to address the unforeseen needs of the plant.

In addition , as noted previously, the Energy Systems GWPO and the Oak Ridge Hydrology Support Program are managed through ORNL's ESD. The GWPO was established to promote consistency among groundwater activities at five DOE facilities operated by Energy Systems.

Other ORNL Programs

Reactor Operations

Operation, maintenance, and support of ORNL's research reactors so that they fulfill their intended isotope production, research, and training functions safely, reliably, and efficiently are the responsibility of Reactor Operations. This work is carried out by the Research Reactors Division with 11 other ORNL divisions and organizations that either conduct reactor-based research or support reactor operations. DOE programmatic funding support is received from ER, and oversight is provided by NE.

ORNL management is committed to maintaining a proactive approach in operating the research reactors. This approach includes securing all resources necessary to ensure safe, efficient, reliable operation; top-management support; and a continued pursuit of excellence. The philosophy of Total Quality Management (TQM) — as well as the requirements of ES&H; Institute of Nuclear Power Operations guidance; and compliance with DOE, OSHA, EPA, and DOT regulations — will continue to be emphasized.

ORNL's operating research reactors include a Category A reactor, the HFIR, and a Category B reactor, the Tower Shielding Reactor II (TSR-II).

Use of HFIR will continue for

- production of transplutonium isotopes,
- neutron-scattering studies for materials science,
- production of high-specific-activity radioisotopes (for medicine, industry, and research),
- materials irradiation (including testing of fuel for the ANS Project),
- gas-cooled reactor fuel studies, and
- neutron activation analysis.

HFIR personnel celebrated the successful completion of the reactor's 300th run in September 1991, and the operating record since the return to full power (85 MW) has been notable. Recognizing that excellence can only be achieved through continuous improvement, enhanced methods, processes, and procedures are initiated regularly.

Improving relations with users is being emphasized by establishing a reputation of reliability, projecting and adhering to forward-looking, 3-month operating schedules, utilizing the HFIR Users Committee to resolve competing demands, enhancing user indoctrination and training, and monitoring user satisfaction.

Both near- and long-term spent-fuel disposition solutions are also receiving priority attention. In the near term, total in-pool storage will be increased from 22 to 24 spaces. Efforts for the long term include obtaining approval of a new spent fuel cask safety analysis report for packaging, initiating fabrication of the new cask, and obtaining an alternate shipping container for a one-time action to dispose of old spent cores (Fig. 5.28).

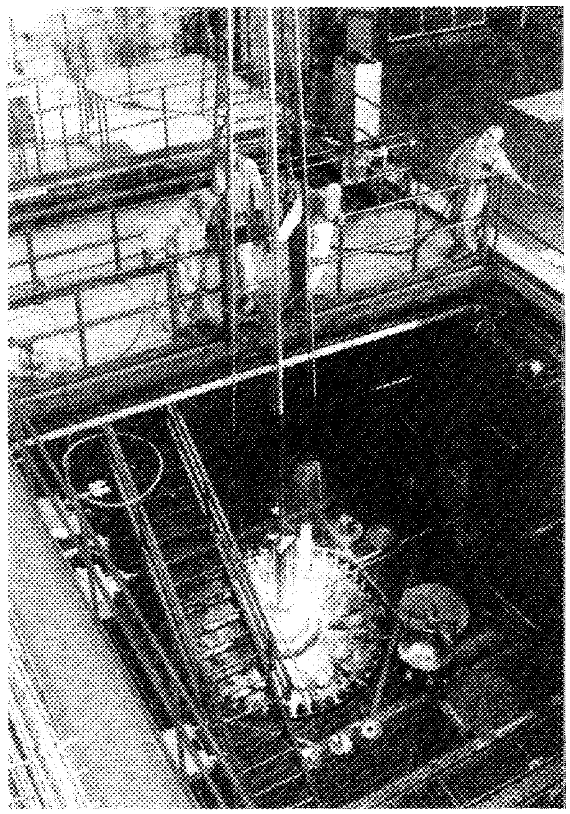

Figure 5.28 Workers dressed in contamination-zone clothing are shown removing spent fuel during a recent defueling of HFIR.

Another important initiative, for which DOE recently approved a technical specification change, is the reactivity measurement of new fuel at HFIR.

In addition, several specific steps are being taken to improve operational performance at HFIR. Low-level contamination occurrences will be reduced through cleanup of pool europium and through work practice upgrades. Upgrades are planned for technical specifications, procedures, and tool decontamination practices; actions also are being taken to reduce the maintenance backlog.

At TSR-II, the Japanese/American Shielding Program of Experimental Research (JASPER) will continue with Phase VIII, Special Materials. An excellent performance record has been achieved in support of JASPER; however, TSR-II may be shut down following completion sof the JASPER program at the end of FY 1992 because of insufficient specific programmatic need and a lack of firm financial commitment. Options and cost estimates have been presented to DOE for (1) continued operation, (2) standby, or (3) proceeding promptly to shut down.

Other ORNL reactors include the Oak Ridge Research Reactor, the HPRR, and the BSR.

The Oak Ridge Research Reactor is shut down and defueled, and plans call for its transfer to the DOE Office of Environmental Restoration and Waste Management early in FY 1993.

A request has been submitted to DOE for approval of the shutdown plan for HPRR, which has also been defueled. DOE has also been asked to apply for its acceptance into the environmental restoration program. Recommendations will be made to DOE for disposition of the reactor core and equipment.

The Bulk Shielding Reactor is also to be shut down because funding is insufficient to support its operation. The shutdown plan, which will call for decommissioning in several years, is being prepared and will be submitted to DOE for approval.

In addition, two reactor facilities are in standby status: the Critical Experiments Facility (CEF), and the PCA. With approval of the alternate method for measuring fresh fuel at HFIR before fuel loading, the CEF will no longer be required. A shutdown plan will be prepared for DOE approval. A proposal has been made to DOE to retain use of the PCA in support of training and education activities for a broad range of users, including the University of Tennessee, Louisiana State University, Mississippi State University, ORAU and DOE, in support of its mathematics and science education initiatives.

Increased support and involvement in the development and construction of the ANS, which will ultimately replace HFIR, will be a significant mission for Reactor Operations.

Two programmatic initiatives are being proposed: the CERR and Retention of the PCA. The CERR, which will help ensure that access to irradiation facilities in nuclear reactors is readily available to meet national research, development, and educational needs, is a continuing initiative, and retention of the PCA is a new initiative.

Several goals for Reactor Operations that are not specific to particular reactors have been identified:

- maintaining a high state of morale and esprit;
- emphasizing improvement of DOE Order 5000.3A reporting performance through staffing, critiques for all unusual occurrence reports and appropriate off-normal occurrence reports, implementing trending data feedback, and suggesting use of the same reporting criteria by all contractors;
- implementing achievable "pursuit of excellence" initiatives while stabilizing operating cost growth;
- taking leadership roles in the Association for Excellence in Reactor Operations Council and Working Groups;
- conducting the second follow-on Comprehensive Safety Assessment and Upgrade Program self-assessment in FY 1993;
- coordinating external audits, evaluations, reviews, and assessments to minimize their impact on operating and support staff;
- working to improve relationships with DOE-OR sponsors, Assistant Secretary for Nuclear Energy organization, and the Office of Energy Research to an excellent state, as viewed by these customers;
- improving productivity of people who are assigned to or are members of the organization;
- empowering people;
- being leaders in implementing DOE training program accreditation;
- implementing a TQM program integrated with the existing Performance Indicators Program; and
- upgrading the formal Self-Assessment Program.

A more detailed strategy for the future has been published.[3] In short, the aim of the Reactor Operations organization is to earn a reputation for being DOE's best reactor M&O contractor.

Robotics and Intelligent Systems Program

The Robotics and Intelligent Systems Program (RISP) serves as the focal point at ORNL for R&D in remote systems, robotics, teleoperation, and related aspects of intelligent machines. The program is interdisciplinary in nature and uses the expertise of scientists and engineers from several research and support divisions of ORNL. RISP conducts research for DOE, DOD, NASA, and other sponsors.

RISP addresses R&D goals for extending human senses and dexterity into unstructured hostile environments. The goals are to develop systems that minimize human risk by allowing effective remote operations in hazardous environments while minimizing human errors and enhancing overall system efficiency through automation of routine or repetitive tasks. The research includes developing an appropriate combination of teleoperation and autonomous operation to achieve the necessary level of task performance while maintaining robust human-machine interaction. The programs cover activities in basic R&D as well as development and full-scale demonstrations of system prototypes, including remote operations and maintenance.

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[3]*Research Reactors Division Strategic Plan, FY 1992–1996*, ORNL/RRD/INT-82, Martin Marietta Energy Systems, Inc., Oak Ridge Natl. Lab., December 1991.

RISP performs R&D for five major DOE programs. Research into intelligent machines is performed for DOE's Office of Basic Energy Sciences Engineering Research Program. Development of robotic systems and techniques to perform surveillance and manipulation functions within a nuclear power plant is pursued for DOE's Office of Nuclear Energy. RISP performs remote equipment design for the TFTR and remote system R&D support for the ITER, a planned cooperative effort among the United States, the CIS, the European Community, and Japan. A major new program for the DOE Office of Environmental Restoration and Waste Management involves national planning and initial technology demonstration of robotics technology for support of the national restoration efforts. Key areas of focus for ORNL include underground storage tanks, buried-waste retrieval, D&D, waste facilities operation, and waste management.

A new activity for FY 1992–1993 will be in robotic development for activities in support of the DOE office in space.

Under the auspices of the U.S. Army Human Engineering Laboratory, RISP personnel are contributing to the Robotics Test Bed Program, an element of the Office of the Secretary of Defense Unmanned Ground Vehicles Master Plan Program, which is assessing opportunities for new robotic combat functions. A U.S. Army Laboratory Command-sponsored Advanced Concepts Technology Program is examining efficient use of combined mobility and manipulation systems. Finally, the Future Armor Rearm System Program is examining automatic ammunition resupply systems for the next generation of the M1 tank. The loading system will provide full nuclear, chemical, and biological contamination protection for soldiers. This project is sponsored by the U.S. Army Program Manager Office for Ammunition Logistics (PM-AMMOLOG). Other programs for PM-AMMOLOG include the Field Artillery Ammunition Processing System, Ammunition Identification Technology, and the Small Emplacement Excavator Project. A new project for FY 1992 will support the NASA Goddard Satellite Servicing Tool Project.

RISP builds upon ORNL's strengths in remote technology, teleoperations, robotics, and autonomous machine research. Program activities that cut across the entire spectrum of related technologies are under way for DOE, DOD, and NASA sponsors. Because research for these agencies often employs similar technologies, significant cost savings can be realized through integration of resources at the working level. The integration of teleoperations and autonomous machines will continue to evolve, and RISP should be a major contributor to that process.

Scientific and Technical Information Centers and Data Bases at ORNL

ORNL hosts a unique combination of technical proficiency, computer programming and processing capability, and information science expertise. With these resources, ORNL has established one of the most extensive and authoritative complexes of scientific data and information analysis centers in the United States. Today, ORNL has more than 200 textual and/or numeric data bases covering various technical disciplines in support of DOE and WFO (non-DOE federal and state agencies).

The development of many of the technical data bases at ORNL follows a similar pattern. A specific scope is defined; comprehensive literature collection, data evaluation, and processing are done; quality assurance by an external review panel is frequently sought; and finally, access to the user is made available through modem or direct connection. Brief descriptions of some selected information centers and data bases follow.

Radiation Shielding Information Center • RSIC was established in 1962 at ORNL. Founded to serve as an Information Analysis Center, RSIC follows guidelines and goals suggested by the Weinberg Panel of the President's Science Advisory Committee, which recognized the important role that these analysis centers could serve in meeting the technical information needs of modern society in the face of the "information explosion." The center provides in-depth coverage of the radiation transport field and is able to serve the needs of a variety of disciplines on an international basis. RSIC staff members collect, organize, evaluate, and disseminate technical information about shielding and protection from the radiation associated with fission and fusion reactors, weapons, outer space, accelerators, medical facilities, and nuclear waste management. The center continues to be a leader in recognizing the role that computer codes and computer-readable data play in any technical discipline and has always treated such as a valid technical information. As a result, the RSIC collections are a valuable resource of radiation transport computing technology. Staff members are on call to answer queries about radiation transport problems and to recommend solution strategies that draw on the technical resources available from the center. RSIC has multiagency funding from DOE (AT—Magnetic Fusion, AF—Nuclear Energy R&D, AJ—Naval Reactors, DB—Nuclear Waste Fund, GB—Weapons Activity, Environmental Restoration and Waste Management, GE—Materials Production, and EW); the NRC; and the Defense Nuclear Agency.

Carbon Dioxide Information Analysis Center • CDIAC, an issue-oriented center, supports the needs of CO_2 research into potentially related environmental consequences such as the "greenhouse effect." Its data holdings include such diverse information as tree-ring chronologies, surface air temperature anomalies, atmospheric CO_2 concentrations, and CO_2 emissions estimates from fossil-fuel burning. Its user constituency comprises basic researchers generating and using raw data; those doing integrated assessments needing multidisciplinary, often derived data; and decision makers needing concise summaries of complex information.

An example of a data package produced by CDIAC is the Carbon Dioxide Emissions Data Base developed at Oak Ridge. Annual global and country CO_2 emissions and per capita emission rates from fossil-fuel burning and cement production are provided. This well-documented data set is the basis for projecting future atmospheric CO_2 concentrations and is used as input for global climate modeling. The newsletter *CDIAC Communications* reaches more than 7000 researchers and decision makers in 145 countries. CDIAC's new series, *Trends*, provides concise presentations of data and descriptive material concerning emissions and atmospheric concentrations of greenhouse gases as well as long-term global and U.S. temperature data. CDIAC is sponsored by DOE's Global Change Research Program.

Toxicology Information Response Center • The Toxicology Information Response Center (TIRC) was established in 1971 to serve as an international center for toxicology and related information. TIRC provides information on individual chemicals, chemical classes, and a wide variety of toxicology-related topics for the scientific, administrative, and public communities. As an information analysis center, TIRC synthesizes comprehensive literature packages according to a user's specific request. Formats include, but are not limited to, custom searches of computerized data bases, manual literature searches, annotated and/or keyworded bibliographies, or written summaries of the literature. TIRC is sponsored by the National Library of Medicine.

ORNL Environmental Restoration Data Management System • The ORNL Environmental Restoration Data Management System was established in 1985 to support compliance with state and federal regulations mandating corrective actions at sites contaminated with radioactive and/or hazardous wastes. The Numeric Data Base serves as a central repository for technical data generated by the program and other applicable studies. Such data are used to evaluate the condition of the environment as it relates to ORNL's past waste management practices and to justify decisions regarding corrective action. The categories of technical data include well-construction parameters, groundwater hydrology and quality, geology, soils/sediments, surface water hydrology and quality, meteorology, biological monitoring, and waste inventory. Based on the data management experience gained for ORNL ERP, ORNL has assumed a key role in developing a consolidated data base for environmental data associated with environmental restoration activities at all Energy Systems facilities.

Oak Ridge Environmental Information System • The Oak Ridge Environmental Information System (OREIS) is being developed to meet the data management/access requirements for environmental data as specified in the Federal Facility Agreement (FFA) and the Tennessee Oversight Agreement. The FFA, a tripartite agreement between DOE, EPA, and the state of Tennessee, requires DOE to maintain one consolidated data base for environmental data generated by environmental programs (Restoration, Compliance, and Surveillance) at DOE facilities on the Oak Ridge Reservation. The major goals of OREIS are to consolidate data of know quality, to maintain the integrity of the data base, and to provide a wide variety of users access to the data. The types of data to be incorporated into OREIS include measurement data from the following environmental disciplines: groundwater, surface water, sediment, soils, air, and biota. OREIS will also contain extensive descriptive and qualifier metadata to help define data quality and to enable end users to analyze the appropriateness of using the data for additional purposes. Another important aspect of the measurements is their spatial context; OREIS will provide a comprehensive library of map data and GIS tools to analyze and display spatial relationships of the data.

Remedial Action Program Information Center • The Remedial Action Program Information Center (RAPIC) was established at ORNL in 1979 to serve the technical information needs of DOE's RAPs; these include SFMP, FUSRAP, and UMTRAP. RAPIC developed and maintains the Nuclear Facility Decommissioning and Site Remedial Actions Data Base, a comprehensive, centralized source of information concerning the scientific, technological, regulatory, and socioeconomic aspects of decommissioning radioactively contaminated facilities and associated site remedial actions. The data base currently contains 7000 records. Ten volumes of a bibliography have been published.[4] In addition to the bibliographic data base, RAPIC developed and maintains the Remedial Action Contacts Data Base, which contains the names, addresses, telephone numbers, technical areas of interest, and program involvement for 1100 individuals involved in contaminated site remediation. RAPIC publishes an annual directory from this data base. RAPIC staff members are available to respond to all requests for technical assistance received from DOE Remedial Action Program staff and contractors.

Environmental Mutagen Information Center • The Environmental Mutagen Information Center (EMIC) was started in 1969 for the purpose of collecting and analyzing experimental data from papers reporting on the evaluation of chemical agents for genotoxicity. As of September 1991, EMIC has indexed more than 78,000 papers reporting on more than 22,000 chemicals.

In 1979 the EPA Genetic Toxicology Program was started using EMIC's collected data file as the basis for its continuing review of short-term tests for genetic toxicology. These data were subjected to strict guidelines for data acceptability, and all evaluations were subjected to review by appropriate panels of experts. The resulting Gene-Tox Data Base contains peer-reviewed evaluations on more than 4600 chemicals evaluated in one or more of 73 short-term bioassays for genotoxicity. This data base provides information allowing correlation between chemical structure and genetic activity.

Information from the EMIC file and the Gene-Tox Data Base is incorporated into considerations for regulatory action and is included in the publications of the International Agency for Research on Cancer. EMIC is sponsored by the EPA and the National Institute of Environmental Health Sciences through the National Library of Medicine; Gene-Tox is sponsored by the EPA.

Chemical Unit Record Estimates • To develop guidelines and limits for controlling chemical substances by a valid scientific approach, various offices within the EPA gather and evaluate information and prepare assessment reports. In 1988 the design and implementation of a comprehensive data base, the Chemical Unit Record Estimates (CURE) Data Base, was begun by the EPA's Office of Health and Environmental Assessment (OHEA) and ORNL to communicate this information within the agency and to facilitate the chemical regulatory process.

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[4] *Nuclear Facility Decommissioning and Site Remedial Actions*, ORNL/EIS-154, Vols. 1–10, Martin Marietta Energy Systems, Oak Ridge Natl. Lab., 1980–1989.

The staff of the Biomedical and Environmental Information Analysis Program has compiled and verified data from a wide range of OHEA documents. CURE is currently comprised of five subfiles: a chemical dictionary, a bibliography file, an experimental data file, a central summary file, and a comment file. The chemical file currently lists 1900 chemicals, all of which have been classified according to the structural categories developed in the EPA Gene-Tox Program. This unique data base will now provide a basis for structural activity to span both genetic toxicology, low dose toxicology, and carcinogenicity. To provide technically sound and user-friendly services to a large range of EPA personnel, the three grades of disseminating vehicles currently being tested at ORNL are

- CURE-PC. This is a stand-alone read-only desktop version of the CURE data base having on-screen menus and prompts with options for direct printing or downloading to a disk for further formatting. Because of space constraints, CURE-PC excludes information from the Health Effects Assessment Summary Tables (HEAST) and the OHEA ADI documentation tables. CURE-PC requires no special software or hookups; however, it needs a hard drive with 13 megabytes available to load, and searches by chemical name, synonym or name fragment, CAS registry number, or document identifiers. CURE-PC includes CURESYN, an excellent easy-to-use desktop resource for document preparation and other applications, and can also be used to find CAS numbers, synonyms, or EPA document information. The last update was in August 1991. A specialized three-megabyte PC version, HEAST-PC, containing information from HEAST and CURESYN for the HEAST compounds, has also been developed. It was last updated on May 15, 1991.
- CURE-Friendly. This is an interactive system with on-screen menus and prompts allowing the searching of the complete CURE database on the Environmental Criteria and Assessment Office in Cincinnati (ECAO-CIN) IBM mainframe computer. This system performs searches by target organ, cancer type, and many other parameters in addition to the search terms for CURE-PC. A variety of output formats are available. This is an excellent easy-to-use resource for document preparation and other applications.
- CURE Central INQUIRE. This is the complete CURE data base on the ECAO-CIN IBM computer. This is an interactive system capable of searching for more than 250 data elements such as chemical and document identifiers, risk estimates, and experimental data parameters. It requires no individual software and uses INQUIRE user language. The output formats are determined by the user. This is an excellent resource for modeling, data associations, or the generation of specialized formats. It was also used to generate the new HEAST.

Human Genome Management Information System • The HGMIS was inaugurated in March 1989 and has completed a very successful year. The HGMIS was established to serve as a primary information resource for DOE's Human Genome Program. As part of its work, HGMIS has produced a quarterly newsletter, established an information data base, and prepared two reports. One of these reports reviews the instrumentation currently used and that proposed for use in the DNA sequencing effort; the other publication is DOE's program report for 1990–91. The work of the HGMIS has provided DOE's OHER with one of its first opportunities to draw attention to its role in the overall effort within the United States to map and sequence the human genome. As a result of its successful work with DOE, the National Center for Human Genome Research (NCHGR) at the NIH has joined DOE in support of HGMIS to produce a joint DOE/NCHGR bimonthly newsletter. The first issue of this joint publication was distributed in April 1990 and is called *The Human Genome News*. A communication resource, *Radon Research Notes*, in support of the DOE Office of Health and Environmental Research, Radon Research Program, began in 1990.

Information Management • The Information Management area has developed desktop publishing techniques for several outreach applications including preparing newsletters, composing course manuals, developing a drinking water regulations poster, preparing and updating reference books on legislation, and composing questionnaires. A PC-based expert system, called NERC (for "NEPA Environmental Review and

Compliance") is under development for the Environmental Monitoring and Compliance Section of the ORNL Environmental and Health Protection Office. NERC is used in preparing documentation of compliance with NEPA requirements and other applicable federal, state, DOE, and ORNL ES&H standards. Additional expert systems include (1) Air Permit Regulations and (2) Determination of RCRA/CERCLA (Comprehensive Environmental Response, Compensation, and Liability Act) Compliance.

Additional areas of interest include the development of a knowledge-based expert system that assists the Y-12 Plant in an internal assessment of environmental regulatory issues; determination of the root cause of an occurrence; performance of environmental surveillance data mapping; and application of hypertext/expert systems for accessing large amounts of diverse information. Furthermore, the Information Management Technology group will initiate effective communication activities for the education of students, the general public, and scientists in research areas of national significance regarding scientific initiatives, such as the Human Genome Program, Radon Program, and the legal and scientific issues originating from regulatory actions and/or mandates. A series of educational materials will be investigated that consist of exhibits, posters, and a multimedia approach including PC-based instruction packages.

Work for Others

Currently, the work undertaken for other federal agencies and organizations outside of DOE and the NRC accounts for about 20% of the Laboratory's total budget. The responsibility for work done on behalf of the NRC remains under ORNL's NRC Programs Office. In addition, WFO accounts for an increasing proportion of the Laboratory's R&D effort (Table 5.32). In light of these developments, the Laboratory is continuing to place emphasis on management and coordination of WFO. A considerable improvement in the overall WFO effort at ORNL has been achieved.

Table 5.32
Work for Others Program resource summary
($ in millions—BA)[a]

	1991	1992	1993	1994
Federal Organizations				
Nuclear Regulatory Commission	18.5	20.7	20.0	20.0
Department of Defense	53.3	34.3	43.0	50.5
National Aeronautics and Space Administration	5.5	5.9	5.0	13.0
Department of Health and Human Services	5.2	4.9	6.7	6.8
Environmental Protection Agency	2.4	1.2	2.9	3.1
National Science Foundation	1.1	0.8	0.2	0.2
Federal Emergency Management Agency	2.5	3.5	4.2	3.4
Agency for International Development	0.8	0.7	0.8	0.8
Other federal agencies	5.0	(1.6)[b]	3.9	3.3
Nonfederal Organizations				
Electric Power Research Institute	2.7	1.1	2.0	1.8
Other nonfederal organizations	5.8	2.4	2.5	1.1
Total	**102.8**	**73.9**	**91.2**	**104.0**

[a]Figures include operating BA and capital equipment, if any.
[b]Parentheses contain negative amounts, indicating a budegetary deobligation. Without the deobligation of $6 million, the amount of BA would have been $4.4 million.

During FY 1991 the WFO Program at ORNL established a steering committee composed of middle management staff from all parts of the Laboratory. The purpose of this committee is threefold: first, to provide for a communications link between upper management and the research staff performing the work for non-DOE agencies; second, to develop solutions to WFO problems that may arise either at the DOE level or from within the Laboratory; and third, to develop and facilitate the growth and expansion of the WFO Program to better complement the Laboratory's DOE missions.

In this latter capacity the committee has been reviewing ten candidate ideas for so-called "big bear" projects. The "big bear" project is defined as involving interdisciplinary research cutting across several divisions and generally scoped at more than $10 million per year.

Of the ten ideas proposed five have been selected for further consideration. These are

- Bioprocessing Technology Development, Demonstration, Test and Evaluation Center. This candidate "big bear" project involves the establishment of a bioprocessing technology facility consisting of a variety of unit operations that would allow for pilot-scale demonstrations and evaluation of proposed technologies and process flow sheets. This center would provide both federal agencies and industry with the ability to scale up from bench models to potential commercial applications.
- Industrial and Municipal Waste Management System. This concept involves performing applied R&D to developing a totally new system and infrastructure to handle both municipal and industrial waste by advanced separation and processing technologies.
- Intelligent Vehicle/Highway System. This proposed project involves developing a new technology to deal with the ever-increasing congestion on the nation's highways by applying both artificial intelligence techniques and new microprocessing technologies.
- Joint Marshall Space Flight Center–ORNL Project for Earth Resources/Remote Sensing Research. This initiative proposes to explore ways for developing joint R&D activities that complement the missions of both organizations. Currently, we are pursuing a joint effort to enable the use of NASA's 30 years of earth resources data to begin understanding global change issues.
- Meeting Energy, Environment, and Other Technology-Related Needs of Developing Countries. This proposal is a complement to an existing Laboratory initiative to assist developing countries as well as former Eastern Bloc nations in dealing with their energy and environmental problems.

In the coming fiscal year, the Laboratory expects to pursue aggressively the development of one or more of these five ideas. It is anticipated that this process will continue in the following years and be driven by the changing research needs at the national level.

Federal Organizations

ORNL funding from non-DOE sponsors is expected to hold at present levels or to increase in the coming years. The following is an agency-by-agency description of the proposed work.

Nuclear Regulatory Commission

Current ORNL efforts for the NRC reflect the commission's priorities, public attitudes requiring a high degree of confidence in the safety of nuclear power, and the maturing of the current generation of U.S. nuclear reactors and certification of the next generation of reactors. Completion of the more than 100 nuclear plants ordered in the 1960s and 1970s, coupled with the upcoming expirations of operating licenses for many of these plants, has shifted NRC research emphasis toward structural and component safety issues, structural aging research, reactor operational data analysis, advanced instrumentation and diagnostics, accident sequence analysis, and license extension requirements. The NRC is also looking toward the future by beginning work to certify activities for several advanced nuclear reactor designs. ORNL funding from the NRC has increased significantly during the past 3 years and is expected to remain stable or to increase slightly over the next several years. Some of the budgetary increases are occurring through ORNL projects that provide a technical basis for the NRC design certification for advanced reactors such as advanced light-water, liquid metal–cooled, high-temperature gas-cooled, Canadian Deuterium-Uranium Reactor (CANDU), and passively safe reactor designs. Environmental and waste management issues remain important and offer potential for additional research involvements.

ORNL performs work primarily for four offices within NRC: the Office of Nuclear Regulatory Research (RES), the Office for Analysis and Evaluation of Operational Data (AEOD), the Office of Nuclear Reactor Regulation (NRR), and the Office of Nuclear Material Safety Safeguards (NMSS). RES, the major sponsor of ORNL activities, conducts comprehensive research programs that lead to regulatory guidelines and standards issued by the commission. NRR is charged with implementing regulations dealing with licensing and inspection of the commercial nuclear power industry. These regulations make strong use of the knowledge obtained from research programs. AEOD collects, analyzes, and evaluates operational safety data to identify areas requiring NRC or industry action. NMSS is charged with overseeing public health and safety licensing activities in the nonreactor nuclear arena.

Nuclear Regulatory Research • During the next several years, the NRC will continue to give priority to research in the areas investigating long-term behavior of reactor pressure vessels and those relating to extension of the operating licenses of existing power plants beyond their original 40-year period. Research into the aging characteristics of plant components has contributed new technologies for nonintrusive evaluation of nuclear plant piping and valves (Fig. 5.29). Technology transfer for some of these developments is occurring through licenses granted to private-sector companies. Another research effort at ORNL is developing both a structural aging handbook and a materials property data base for concrete structures in U.S. nuclear power plants.

Research on fission product behavior for LWRs under severe accident conditions has decreased somewhat, but important research at ORNL continues to help resolve regulatory issues in this area. Recent ORNL work has provided a basis for possible modifications of the portions of the NRC Regulatory Guides 1.3 and 1.4 that deal with iodine chemical forms in containment. Efforts in this area may continue at a modest level for several years.

Other research initiatives at ORNL contribute to the NRC's Severe Accident Research Plan (SARP). These efforts include work on boiling water reactor (BWR) core-melt progression and in-vessel strategies for addressing potential severe accident conditions. ORNL staff collaborate with Sandia National Laboratory and INEL on improving and extending the applicability of the MELCOR Code for LWRs to scenarios for severe accidents in BWRs. Other severe accident code development work supports NRC cooperative research agreements with Germany (CORA-BWR experiments) and with seven other foreign nations to develop and validate computer codes for modeling fission product

Figure 5.29 **Aging degradation of check valves results in substantial expense and significant operating difficulties for nuclear power plants. Howard Haynes (left) and Don Casada developed nonintrusive magnetic-flux monitoring techniques that allow plant personnel to determine the condition of the valve internals without valve disassembly or removal from service. Their work was featured in the February 1992 (Vol. 35) issue of *Nuclear News*.**

behavior and core-melt progression under severe accident conditions (Cooperative Severe Accident Research Partners).

The NRC continues to place high priority on research to ensure the integrity of reactor pressure vessels in commercial nuclear power plants. ORNL is the lead laboratory for this work, which includes the Heavy-Section Steel Technology Program, the Heavy-Section Steel Irradiation Program, and the Surveillance Data Base, Analysis, and Standardization (SAS) Program.

The HSST Program investigates issues concerned with validating safety margins relative to prevention of reactor vessel fracture under all feasible loading conditions. Large-scale fracture experiments and advanced analyses are being performed to investigate shallow flaws and localized thermally induced constraints associated with emergency core-cooling scenarios. Pressure vessel investigations have expanded during FY 1992 to include supplemental pressure vessel safety research for advanced LWR designs.

The Heavy-Section Steel Irradiation Program is extending the basic understanding of physical mechanisms associated with radiation-induced damage (embrittlement) in pressure vessel steels. Radiation experiments are also performed to verify the applicability of damage models to prototypically thick steel sections. One aspect of the program is a study of the degree to which degraded steel properties recover when thick sections of irradiated steel are annealed at relatively high temperatures for sustained periods of time. R&D activities relating to reactor pressure vessel integrity, particularly the fracture mechanics and irradiation embrittlement studies, are important to the NRC and to the nation's nuclear industry (Figs. 5.30 and 5.31).

Figure 5.30 During a wrap-up session of his August 1991 visit to ORNL, NRC Commissioner Kenneth Rogers (second from left) assured Energy Systems President Clyde Hopkins (second from right) that ORNL staff are continuing to perform "good, important work for the NRC." Others participating in the session included (left to right) Gail Marcus and Jack Scarborough of Commissioner Rogers' staff; Martha Kass and Dick Egli of DOE-OR; Claude Pugh, Director of NRC Programs at ORNL; and Alex Zucker, former ORNL Associate Director for Nuclear Technologies. The Commissioner's visit was primarily to learn more of the Laboratory's R&D activities relating to reactor pressure vessel integrity, irradiation embrittlement, and the Nuclear Operations Analysis Center data bases on operations of commercial nuclear power plants.

The SAS Program maintains for the NRC the national operational surveillance data base for commercial reactors. These data are used to develop improved correlations that are used by NRC to predict the state of embrittlement for vessels in operating reactors. These results have direct applications in license renewal and life-extension assessments, which will continue to be major NRC concerns. Increased attention is being given to determining the compatibility of foreign data with the U.S. data base and to the possibility of their combined use.

ORNL has assisted the NRC with the development of a generic environmental impact statement appropriate for license renewal rulemaking. It has been listed in the

Figure 5.31 Tim Theiss (left), of the Engineering Technology Division, points out to Commissioner Rogers and NRC staff members Jack Scarborough and Gail Marcus some important features of pressure vessel steel specimens tested by ORNL's Heavy-Section Steel Technology Program.

Federal Register for public comment. ORNL will assess the comments and will assist the NRC in the resolution process.

The NRC is sponsoring safety research to support certification of advanced reactors such as HTGRs, LMRs, and CANDU-3. ORNL provides support on thermal hydraulics code validation, assessment of severe accident evaluation, instrumentation and controls methodologies, and pressure vessel studies. As the NRC extends its considerations of the advanced reactor designs, ORNL's support efforts are expected to increase. For example, new projects that began in this area during FY 1992 include assessments of advanced digital instrumentation and control systems, material studies, and severe-accident analyses.

Additional ORNL projects for the RES that were started in FY 1992 are in the areas of human factors research and evaluation, engineering systems assessments, and review of radioactive transport specification packages.

For more than 30 years, the journal *Nuclear Safety*, coordinated by ORNL staff and jointly published by NRC and DOE, has been recognized for its outstanding contributions to the provision of safety information to the nuclear industry. Publication support for the journal is expected to continue.

Analysis and Evaluation of Operational Data • AEOD's mission within the NRC is to serve as focal point for the continuing independent assessment of operational performance of nuclear power plants. The several projects sponsored by AEOD at ORNL emphasize the collection, review, analysis, and evaluation of plant safety performance data. The pioneering Accident Sequence Precursor Project identifies nuclear power plant events considered precursors to potential severe core-damage accidents and uses risk assessment methodologies to determine the quantitative significance of events.

Among active projects for AEOD, ORNL is (1) providing support to assist in the resolution of operational performance issues, (2) benchmarking the operating record of individual power plants for diagnostic assessments, (3) trending events, (4) providing on-call assistance, and (5) responding to inquiries from NRC staff.

ORNL operates and maintains the NRC's official data base on reportable operational events at commercial power plants—the Sequence Coding and Search System (SCSS). Used by NRC to construct event sequences, the SCSS is a highly structured system that supports detailed searches of operational occurrences. Other data systems are maintained at ORNL on (1) foreign reactor events, (2) international incident reports, and (3) power plant performance indicator data and appropriate statistical models developed for the interpretation of these data. ORNL provides extensive support to the AEOD through NRC's Performance Indicator Program by evaluating events as to their cause, monitoring changes in plant performance, and indicating corrective actions needed to prevent plants from developing serious problems. In a new effort, ORNL is assisting AEOD in the development of a quarterly publication, *Power Reactors: Events and Issues*, which will highlight case studies and evaluations performed by AEOD to provide feedback on "lessons learned" from these events for the nuclear industry.

Nuclear Reactor Regulation • Using expertise developed in RES programs, ORNL provides technical consultation and assistance to NRR. On-call assistance is currently provided in the interpretation of nonintrusive plant component evaluation data, in analyses of fuel stability, in the review of licensing documentation, in evaluations of BWR stability phenomena, and in failure modes and effects analysis. A significant effort also involves investigations of the thermal-hydraulic stability phenomena of BWR cores or fuel assemblies. ORNL has emphasized its capabilities to NRR, and NRR has increased in scope and funding of work at ORNL to include analyses of potential accident sequence precursor events occurring during low-power or shutdown operation, evaluations of materials irradiation test data, and water chemistry standardization for nuclear power plants.

ORNL provides technical assistance in updating NRC's health physics positions on inspection, enforcement, and licensing issues. The Health Physics Positions Database is used both by Headquarters and Regional staff to ensure uniformity in licensing actions.

Economic analyses and reviews of safety-related systems are also being conducted to support the NRR's advanced reactor design certification efforts. Further increases in NRR work is expected during the next few years to assist NRC's advanced reactor design review and nuclear plant license extension activities.

Nuclear Material Safety and Safeguards • The NMSS sponsors several projects at ORNL, including computer programming and documentation of criticality safety, shielding and thermal analyses of nuclear fuel facilities and package designs, licensing of enrichment facilities, and review of terminated radioactive materials-handling facility license files. These activities are continuing through and beyond FY 1992. Other recently initiated NMSS projects provide technical support in reviewing the design, construction, operation, and performance of low-level waste facilities and assist in developing a national profile on commercially generated low-level radioactive mixed waste. These efforts continue in FY 1992 and beyond.

Two new projects have been initiated for the NMSS. The first project provides technical assistance for assessing the effectiveness of the Low-Enriched Uranium Reform Rule and its implementation in maintaining the commission's desired level of safeguards for users of nonstrategic special nuclear materials. The second project involves reviewing terminated license files to determine whether the sites and licensees were demonstrated to meet present criteria for release of the site, based on public health and safety considerations, and whether the information provided by the licensee was sufficient to determine releasability. Funding for NMSS work is expected to remain relatively stable or to increase over the planning period.

Other Offices

The Laboratory provides technical assistance in inventory verification, analysis of special nuclear materials samples, preparation of site-specific material standards, and review of environmental assessments and operating procedural changes. ORNL staff members also provide consultation and on-call assistance to the NRC Advisory Committee on Reactor Safeguards and the Advisory Committee on Nuclear Waste.

U.S. Department of Defense

ORNL carries out R&D for the major DOD services—U.S. Army, Navy, Marines, and Air Force—as well as for joint agencies such as the Defense Nuclear Agency, the Defense Advanced Research Project Agency (DARPA), SDIO, and the U.S. Transportation Command (USTRANSCOM). Several projects, such as MODIL and the Seawolf project, are managed by non-ORNL Energy Systems organizations, and all projects are considered part of an Energy Systems centralized organization.

Army • ORNL research for the Army includes programs in materials science and technology, optics, instrumentation and control systems, robotics and intelligent systems, man-machine interface technology, transportation systems, operations research, and environmental analysis. In addition to the Army-funded projects, ORNL also has an Army optics development program funded by the U.S. Army Strategic Defense Command. The program involves mirrors, baffles, and windows for broadband type sensors.

ORNL's program with the U.S. Army Research Laboratory (ARL) has expanded significantly and now involves the transfer of DOE technologies to several ARL agencies. These programs focus on ORNL's unique capabilities in advanced materials and robotics, and they also include basic and applied science. ARL has proposed a major initiative to establish a 5-year collaborative research program with all DOE laboratories beginning in FY 1993. Oak Ridge staff have helped provide the leadership in planning the cooperative program with the Army.

Work will continue on the major research initiative concerning the aging of materials used in Army munitions stockpiles. This project is under the aegis of the Armament, Chemical and Munitions Command. Also, work will continue in advanced materials R&D—taking particular advantage of ORNL's well-recognized expertise in composites, ceramics, carbon/carbon bonding, intermetallics, and related technologies. Research will begin on mathematical and computational modeling of crack propagation in materials. These projects are designed for the development of advanced armor and shielding as well as lighter-weight components for increased mobility of weapon systems and vehicles. Advanced shielding materials and processing concepts (microwave sintering ceramics for armor) will be evaluated for DARPA, the Tank Automotive Command, the Ballistics Research Laboratory, and other agencies. In addition, work continues on advanced materials for reentry vehicles and space applications for the Space Development Command.

Other recently launched initiatives that are continuing to expand deal with advanced instrumentation and robotics and intelligent systems technology, including advanced robotics concepts for ARL and related prototypic applications for the Army's Human Engineering Laboratory, Ft. Belvoir Research and Development Center, and other related agencies. The use of tomography and other technologies to detect underground tunnels and features will be expanded. New programs in laser and communications technology for the battlefield are also planned. Stand-off detection of agents also will be studied.

ORNL continues to support major environmental assessments. ORNL is assisting the Army's program manager for chemical demilitarization to prepare site-specific EISs for the on-site disposal of chemical agents and munitions stored at eight continental U.S. locations and one non-U.S. location (i.e., Johnston Island in the Pacific Ocean). ORNL is assisting the Army in assessing the impacts of destroying the U.S. European stockpile of chemical munitions at the Johnston Island disposal facility. ORNL also is providing support in the development of emergency response plans for installations that store chemical agents and munitions. For the DOD Installation Restoration Program ORNL is assisting the Army's Toxic and Hazardous Materials Agency on scientific and regulatory issues and in defining cleanup criteria for hazardous waste sites. The Army has many waste sites throughout the country that must be remediated according to EPA policies and guidelines. ORNL scientists are using their knowledge of the EPA's regulations and risk assessment strategies to define the necessary cleanup criteria for the Army. New instrumentation to support the test and evaluation community will be started for Test and Evaluation Command. Advanced artillery system concepts and designs will be evaluated for the Combat Artillery School.

ORNL will expand its environmental analyses of the potential impacts of changing military operations or broader programmatic missions at specific sites. This work includes developing new environmental measurement and analytic techniques for laboratory and field applications. Work is also expanding in analytical chemistry and environmental technology to characterize chemicals (such as military fuels) and their by-products and to develop biological indicators for environmental and health assessments.

R&D for the Army in operations research and transportation systems, energy conservation, energy security, fuels research, and advanced engineering command continued to expand. Included among these projects were the development of telecommunications systems prototypes and a model for the coordination of routing and scheduling military convoys over the U.S. highway system. Research to develop regional economic assessment decision support systems for recruiting and for force structure analysis for the National Guard Bureau is expected to grow moderately over the planning period. ORNL is providing analytical techniques to this bureau for force structure and mobilization planning and related civilian missions.

The Army's Chemical Research, Development, and Engineering Center is supporting efforts to refine techniques for the detection of biological and chemical materials in the air. Staff from HASRD are using various combinations of lasers, optical fibers, and advanced spectroscopic techniques in support of the Army's efforts to develop instruments that can be used on modern battlefields.

For chemical hazard communication, ORNL is providing technical assistance to the Army Environmental Hygiene Agency to prepare Material Safety Data Sheets for incorporation into DOD's Hazardous Material Information System. In addition, toxicity values are developed for hazard assessments at Superfund sites.

ATD has performed several "pre-procurement" projects for the Army. Included in this was a project to demonstrate that motor/generator sets procured by the Army could meet all design requirements while significantly reducing the total weight if major portions of the sets were fabricated from commercially available composites. Demonstration prototypes were tested against the design requirements and then made available to the vendors as examples of technology to be exploited in future procurements.

In another Army program the ATD is developing procurement acceptance procedures for state-of-the-art instrumentation. Typically, the Army develops a performance specification for the next generation electronic component; however, because it is a state-of-the-art component, there is no conventional test method to verify that it meets the performance specification. To overcome this dilemma, the ATD has developed instrumentation and procedures to be used in "First Article Acceptance Testing" to verify these state-of-the-art instruments meet the performance specification.

Navy and Marine Corps • ORNL conducts research for the Navy and Marine Corps in engineering systems, instrumentation, data systems, reliability and maintenance, materials R&D, fuel supply and use, diesel testing, human-factors engineering, energy conservation, and waste disposal.

This research has diverse applications and has contributed significantly to many Navy and Marine Corps programs located at a variety of Navy laboratories and institutions. ORNL's Navy Mobility Fuels Forecasting System has been used to estimate the availability and quality of Navy fuels for future-year business-as-usual and petroleum supply disruption scenarios originating in the Persian Gulf and other world regions. The forecasting system has also been used to analyze the impacts of democratization of Eastern Europe and related events. In research cosponsored by the Navy and DOE, the forecasting system is now being used to evaluate the fuel production effects of the U.S. Clean Air Act.

ORNL plays an important role in instrumentation and engineering R&D for the Carderock Division—Naval Surface Warfare Center (CD-NSWC), formerly the David W. Taylor Research Center. The CD-NSWC is the Navy's primary research, development, test, and evaluation center for naval vehicles. Two primary areas of interest to the CD-NSWC are ship and submarine silencing and methods to design and test high-strength hulls and components. ORNL assists the CD-NSWC in the design and development of R&D instrumentation systems for experimental models of proposed submarine designs, the development of new ship and submarine designs, and support for the current fleet. In addition to this work, ORNL continues to evaluate new technologies for the Navy's advanced submarine R&D program, which is planned to support the new emphasis on DARPA and the Navy.

ORNL provides a variety of design, engineering, and development support for the Coastal Systems Station (formerly the Naval Coastal Systems Center) in the areas of submarine countermeasures, amphibious warfare, naval special warfare, and mines and mine countermeasures. ORNL is also providing electronics development and human factors engineering support for the Naval Medical Research Institute in areas related to divers and diving.

For the Naval Air Systems Command, ORNL research involves the design and evaluation of advanced part-task trainers for Navy missile systems. Issues related to the ability to ensure high levels of training effectiveness and the relationship between trainer fidelity and human performance are key concerns involved with appropriate mental models, and subsequently, effective trainer interface design. R&D continues also on instrumentation and equipment reliability and maintenance that will explore methods to determine optimal times for preventive maintenance. ORNL research also involves productive base analysis that addresses the capability of U.S. industry to produce defense material in a time of war. Research continues on new techniques to modernize naval systems, especially in the areas of logistics, mobilization planning and modeling, command and control, marine telecommunications, environmental technology, computer-aided instruction, and robotics and intelligent systems.

For the Naval Undersea Warfare Center, formerly the Navy Underwater Systems Center, ORNL will use quadrupole superconducting magnets to construct a long dipole field to be used in propulsion experiments at the center. Other projects include electronic component design cost-effectiveness, life-cycle analysis, and prototype development for the Naval Sea Logistics Center, a computer-aided research project for the Naval Sea Systems Command.

ORNL provides technical assistance to the Navy Environmental Health Center in Norfolk, Virginia, by preparing Material Safety Data Sheets and hazardous material assessment reports to support the hazard communication standards of the Occupational Safety and Health Act, the Superfund Amendment Reauthorization Act, and the right to know of the community.

ORNL has conducted several materials R&D programs for the Navy. Among them is a program to fabricate polymer matrix composite pressure hull prototypes for submersible vehicles.

ORNL staff are providing technical assistance to the Navy's Radon Assessment and Mitigation Program. To date, the assistance has included planning, data management, quality assurance, and quality control for the identification of structures with elevated radon concentrations at naval facilities worldwide. The key components are screening and assessment measurements, quick-response verification of possibly high radon levels, and mitigation training. Mitigation training exercises are being given to Air Force personnel as well. In a General Accounting Office review of several federal agency radon programs, the Navy's program was well received and has caused other agencies (U.S. Postal Service, U.S. Department of Housing and Urban Development, DOE) to make inquiries to the Hazardous Waste RAP about the feasibility of starting similar programs.

Air Force • For the Air Force, ORNL performs research on environmental systems, advanced materials R&D, advanced fuels research, data systems, waste management, environmental research and other related activities. A major economic analysis activity supports the Air Force Civil Engineering Support Agency (AFCESA) and the Air Forces Major commands. ORNL performs economic analysis and technical support for evaluating the use of private-sector financing to augment government funding to achieve a more rapid delivery of new facilities and services. Other support to the AFCESA includes the evaluation of Air Force base energy requirements to assess whether energy requirements can be met cost-effectively by increased coal consumption.

In support of IRP, ORNL is assisting the Air Force's toxicology program at Wright-Patterson Air Force Base. An extensive update and revision of the original three-volume IRP toxicology guide was completed. The resulting four-volume guide covering 70 organic compounds, incorporated the latest available information on state and federal regulatory status, health hazard data, analytical techniques, environmental fate, and a wide range of toxicologic data, including carcinogenicity, genotoxicity, teratogenicity, and short-term and long-term exposure effects on humans and laboratory species. In addition, all of the data were incorporated into an on-line, relational data base using the ORACLE data base management system. The present work involves compilation, analysis, and presentation of similar information on a series of metals comprising more than 80 individual compounds or salts that are of concern to the Air Force. This work was completed in November 1990. Updates to the five-volume toxicology guide will begin in 1993. New information-disseminating technology, such as CD-ROM and laser disk readers, will be evaluated and implemented.

For several years, the ATD has been performing R&D in thermoplastic composite materials and managing the Thermoplastics for Space (TOPS) Program for the Air Force. It is anticipated that this work will be expanded to include an Adaptive Structures Program during this fiscal year.

For the Wright Research and Development Center (WRDC), ORNL is performing research in multisensor integration algorithms for hypercube computer architectures. Hypercube computer architectures offer supercomputer capabilities in a small volume (which is ideally suited for robots and satellites). This research augments and complements DOE robotics multisensor integration research being carried out at ORNL. Also for WRDC, ORNL is working on the development and evaluation of thermoplastic materials for space applications, the development of design/analysis and fabrication techniques for thick composites, and the design and evaluation of foil-lined composites for cryogenic environment applications.

A major environmental R&D activity will continue to support the Air Force Environmental Impact Analysis Process in which both programmatic and site-specific analyses of Air Force actions are addressed. ORNL conducts environmental compliance assessments for various Air Force commands.

In the manufacture of technologically advanced air frames, quality control is extremely important. Staff from HASRD are identifying pertinent spectroscopic properties of advanced composite materials. The results of this work will be applied by the Air Force to the development of nondestructive tests that can be used during manufacture.

Military Transportation • One of the most successful WFO programmatic areas involves the R&D for the DOD transportation agencies. To coordinate this work with our other research in transportation systems, ORNL management created a new Center for Transportation Analysis. The center will blend together complementary work for DOE, DOT, and the various defense transportation agencies—linking such WFO sponsors as the Federal Aviation Administration, the Federal Highway Administration (FHWA), the Military Airlift Command (MAC), the Military Sealift Command (MSC), the Military Traffic Management Command (MTMC), and USTRANSCOM, among others.

ORNL's Center for Transportation Analysis is a primary resource for technical innovations to improve the utilization of DOD transportation resources. The center's staff has won wide recognition throughout the military for their broad range of contributions to increase the efficiency of both peacetime and wartime moves. Although most work to date has been in the area of scheduling and transportation analysis for USTRANSCOM and its three components, MAC, MSC, and MTMC, FY 1990 efforts also supported transportation resource planning for Joint Staff logistics studies and for DARPA transportation planning research.

Center staff are now engaged in development of a comprehensive system that will help manage MAC's peacetime and wartime transportation missions termed Airlift Deployment Analysis System. This system was selected as the exclusive airlift planning and scheduling tool for the "Operation Desert Shield/Desert Storm" deployment of U.S.

military personnel and material to Saudi Arabia. The peacetime portion of the system will help MAC schedule routine missions to meet shipping demands at minimum cost. The wartime portion of the system will support deliberate planning and the development of contingency plans during peacetime as well as time-sensitive planning and operations support in times of crisis.

Work in FY 1990 for USTRANSCOM resulted in development of a microcomputer-based system for estimating strategic cargo and personnel flows of an overseas deployment. The system was used by the command's emergency operations center during the recent "Desert Shield" deployment. Earlier work by ORNL, Energy Systems Computing and Telecommunications Division, and UT personnel resulted in a sophisticated sealift scheduler for the MSC and a continental U.S. traffic management prototype for the MTMC. The sealift scheduler is designed so that the same algorithm can be used in the MSC's large IBM mainframe and USTRANSCOM's microcomputer-based flow estimator. The MTMC deployment traffic management prototype is used to analyze transportation mode assignments and route military traffic to airfields and seaports during an overseas deployment.

Transportation Center staff are developing a system to assist the MTMC with analysis of the effectiveness of DOD personal property moves. The system will be a pioneer of use of networked workstations and personal computers to implement a command-wide "corporate" data base. The work is a follow-on to an effort that implemented a wide-area data communications network between MTMC and shippers at Army installations throughout the country.

Defense Nuclear Agency • ORNL is performing research for the Defense Nuclear Agency in support of the Human Response Program. This effort addresses the human factor in the military nuclear environment through models and data bases that predict the human response in all nuclear threat situations. The research is carried out through expert integration of state-of-the-art radiation transport and human response data. ORNL is satisfying the conditions for this program as defined under the DOD Qualified Research Requirements documents through a multiphased plan that includes definition and analytic validation of the initial and protracted radiation environments, shielding calculations for tactical armored vehicles, and an extensive intercomparison between the existing and newly developed methods to assess radiation impacts on military vehicles and human beings. The Defense Nuclear Agency also is supporting research at ORNL to define more accurately the effects of nuclear weapon radiation on the victims at Hiroshima and Nagasaki. It also supports RSIC to provide information analysis center activities for Defense Nuclear Agency contractors doing radiation transport R&D.

A portable system to weigh vehicles while they are in motion is being developed under the sponsorship of the Defense Nuclear Agency. A proof-of-principal Weigh-in-Motion System was developed with DOE funding and used as a demonstration unit for the Defense Nuclear Agency. The Defense Nuclear Agency has since sponsored further development of the system to meet their requirements of 1% accuracy over a range of 0.5 to 30 metric tons. The Weigh-in-Motion System is a fiber-optic-based sensor that extends the ATD's embedded sensor/smart structure technology.

Strategic Defense Initiative Organization • Work is currently being performed on neutral particle beams, lightweight power and energy-storage systems, optical components, survivability and shielding, flywheels, parallel computing and sensor integration, and lightweight structures made from high-temperature materials. The level of effort for the coming years will be heavily influenced by the national Strategic Defense Initiative (SDI) policy set by the Administration.

The SDI Survivable Optics Manufacturing Operations Development Integration Laboratory is a major SDI initiative. This program will continue to examine and to integrate optical technologies into an overall fabrication process and to examine the broad scope of the manufacturing system as opposed to the singular development of manufacturing subsystems. It will provide the integrated technology that, if implemented by private industry, would achieve the stated SDI optical component goals.

Two major ongoing programs in SDI are the optics development and shielding programs. Under the direction of the U.S. Army Strategic Defense Command, Huntsville, Alabama, expertise and facilities available within Energy Systems for mirror and lens fabrication, telescope fabrication and snap-together assembly, radiation testing, and optical characterization are being applied to the development of radiation-hardened, passive optical components. These components are of interest to SDI and potentially to other areas within DOD and NASA. Energy Systems capabilities are also being applied to develop shields to protect satellites against high-kinetic-energy particles, high-energy lasers, and particle beams as well as natural and man-made radiation. ORNL staff members are performing an advisory role for the federal government as part of the technical advisory group on Superconducting Magnetic Energy Storage Project.

Other U.S. Department of Defense Agencies • For DARPA, the Laboratory has initiated a project on artificial intelligence for transportation planning research. Work will expand on R&D in advanced parallel computing for the Worldwide Military Command and Control Information Systems Program Office.

National Aeronautics and Space Administration

Much of the R&D that ORNL performs for NASA is managed by non-ORNL Energy Systems organizations. For NASA, ORNL is performing basic research to produce a conceptual design for equipment required to levitate and melt niobium in space. Basic research is required to increase the efficiency of the rf generator substantially and to design special water-cooled coils to levitate and to heat metal samples suspended in space. The modular design concept is proposed to provide hardware that can be adapted for use by NASA principal investigators who are planning such experiments.

NASA funding is anticipated for ORNL to design and to implement major components of global vegetation dynamic models, to contribute to the formation of comprehensive earth system models, and to consult in the design of remote-sensing satellites from the standpoint of model data requirements and application of vegetation models to interpret satellite imagery. We anticipate new initiatives addressing impacts of climate change on natural resources; support of joint research in mathematical, statistical, and computational methods is expected from NASA's global change program. ORNL is also working with the TVA and NASA to propose new work that would investigate the effects of climate change on water resources in the southeastern United States.

NASA's recent initiative to put man on the moon and Mars on a continuing basis will create an opportunity for ORNL to support the development of reliable space nuclear power systems for both electrical and propulsion applications. Work in this area is already under way and is expected to grow.

In other current work for NASA, ORNL is developing advanced high-temperature thermal storage technology using metallic phase-change media for advanced solar dynamic power systems. The effort includes modeling of system thermal performance and prototype development and testing. This work is an extension of thermal energy storage work being performed for DOE. NASA also provides funding for RISP, including robotic and human-system interface technology for space missions.

For the NASA-Lewis Research Center, ORNL will undertake the conceptual design of (1) a number of magnet systems and provide the amount of conductors and approximate cost for each and (2) scaling rules that can be used to estimate other solenoidal magnets of the type designed. The level of support for this work increased in FY 1992 and is expected to continue to increase in FY 1993.

A possible new initiative is the development of advanced thermal management techniques that will be required to meet system performance requirements for space applications. Components include radiators, heat pumps, and heat pipes. The thermal rejection components will be fabricated of highly conducting composites to meet mass restrictions. Advanced heat-actuated low-maintenance heat pumps will be developed to improve system reliability and to reduce system mass to the point required for space or planetary deployment. A continuing initiative, the Nuclear Propulsion for Space Exploration Initiative, is included in this section under the "Assistant Secretary for Nuclear Energy" subsection.

At the request of NASA, ORNL has prepared a proposal to be designated as a NASA EOSDIS DAAC (EOS-Earth Observing System; DIS-Data and Information System; DAAC-Distributed Active Archive Center). ORNL would be the eighth NASA DAAC, a data center for biogeochemical dynamics. As a DAAC, ORNL would receive funding from NASA for the establishment of a center for the acquisition, quality assurance, documentation, and distribution of land-based data related to biogeochemical dynamics, including compounds such as CO_2, N_2O, and O_3. Development of these data sets is crucial to U.S. Global Change Research Program and to DOE's component in that program and DOE's scientific mission. ORNL has long been a leader in the management and analysis of environmental research data. DOE's CDIAC has a worldwide reputation for quality data management of CO_2 and related global change variables. The location of the DAAC at ORNL will also complement DOE's existing ARM Archive activity, ensuring a close tie between the two largest single components of the U.S. Global Change Research Program.

U.S. Department of Health and Human Services

The Department of Health and Human Services (DHHS) supports research, in-literature evaluation, analysis, and database development in carcinogenesis, genetics, and toxicology. Its funding is expected to remain reasonably constant. The majority of DHHS funding is from the NIH; some funding is from the U.S. Food and Drug Administration. Various branches of the NIH that support ORNL's programs are

- the National Cancer Institute (NCI);
- the National Center for Toxicological Research;
- the National Institute of Environmental Health Sciences (NIEHS);
- the National Heart, Lung, and Blood Institute;
- the National Center for Human Genome Research (NCHGR);
- the National Institute of Child Health and Human Development (NICHHD);
- the National Institute of General Medical Sciences (NIGMS);
- the National Institute on Drug Abuse;
- the National Library of Medicine;
- the National Toxicology Program;
- the Agency for Toxic Substances and Disease Registry (ATSDR); and
- the Office of the Inspector General.

ORNL is providing guidance for the ATSDR on the performance of health assessments at hazardous waste sites on the Superfund List. Methodologies are being developed to predict acute and chronic health effects resulting from exposure to hazardous chemicals. In addition, ORNL will be providing technical expertise in updating and evaluating ATSDR's Toxicological Profiles; recommending chemical candidates for further testing to fulfill information gaps in health risk assessment; developing a Geographical Information System for use in evaluating health effects at the nation's Superfund sites; evaluating the effectiveness of Toxicological Profiles; and developing regulatory information data bases.

The NCI is supporting a study of neoplastic changes in tracheal epithelial cells. A major change is in the response to the factors that induce cell differentiation: in this context, the role of TGF-β is being investigated. The response to this growth factor, and therefore its influence, changes as cells progress from preneoplasia to neoplasia. The NCI also supports the analysis of EGF/EGF receptor interactions and their mitogenic consequences as illuminated by studies with specifically modified EGF variants. Environmental exposures usually involve more than one carcinogen or toxic agent, yet little is known about the interactions of such agents. The development of a flow-through trachael implant system has made it possible, with NCI funding, to study the effects on trachael cells of mixture of agents and sequential exposures at the molecular, cellular, and tissue levels.

NIEHS supports large projects on genetic and developmental effects of chemicals. The mechanisms of gene-mutation and chromosome-aberration induction in germ cells are investigated, and the molecular and cytogenetic nature of the genetic lesions are analyzed. Also studied are the organismic effects in first-generation offspring of chemically exposed mice.

The NICHHD supports a project to generate transgenic lines of mice by DNA injection into fertilized eggs.

The NCHGR supports saturation mutagenesis (using a point-mutation inducer) within defined segments of the mouse genome for physical/functional mapping. The NCHGR also supports production of the newsletter, *Human Genome News*, in collaboration with DOE/OHER.

With support from NIEHS, the hypothesis that gene transposition is an important part of the mechanism of carcinogens induced by environmental agents is being tested. A mouse-model system is being used to investigate whether the mouse chromosomal long terminal repeats, containing retroviral gene elements, are capable of initiating genetic transposition following the genotoxic injury of the cell.

The National Institute of Aging, NICHHD, and, indirectly, the National Institute of Alcoholism and Alcohol Abuse, support projects for the cryopreservation of embryos of mice that have distinctive genetic properties.

Continuing studies on the crystallographic analysis of nucleosome structure, with the goal of 3-Å resolution, is in part supported by NIGMS.

U.S. Environmental Protection Agency

ORNL's EPA program addresses numerous health, environmental, and economic problems and issues, including the ecological effects of global change, toxic effects of pollutants associated with energy production processes and waste disposal, methods for environmental monitoring and assessment, and assessment of environmental impacts of biomass energy technologies. Health and environmental risk analysis epidemiological studies continue to be important components of this work. ORNL is also involved in the development of biomarkers for assessing exposure and effects of environmental contaminants. ORNL is continuing its evaluation of the economic viability of recycling solid waste; emphasis is placed on plastics recycling. In addition, work is under way on evaluating various economic incentive programs that might be implemented to promote additional recycling, source reduction of solid waste, and use of biomass energy.

The EPA supports research on the mechanisms that lead to congenital anomalies following the exposure of very early mouse embryos to certain chemicals. These mechanisms may include interference with gene expression in the conceptus.

The EPA is also supporting research at ORNL to evaluate the impact of municipal waste incineration on human exposure to pollutants through the terrestrial food chain. ORNL is developing a computerized terrestrial food-chain model to aid in this analysis. The EPA is supporting experiments to investigate the high incidence of congenital defects produced by exposures of fertilized mouse eggs to certain chemicals.

Biologically based assessment of the human risk from exposure to hazardous chemicals involves a series of judgmental decisions concerning unresolved issues in risk assessment. ORNL staff members, with EPA and NSF support, are developing biologically based pharmacokinetic and pharmacodynamic methodologies to evaluate the scientific bases of these assumptions. Pharmacokinetic models predict chemical transport and metabolism across routes of administration, across species, and through temporal variations in time; pharmacodynamic models relate genetic mutation frequencies and cell-turnover dynamics to the epidemiology of cancer in animal and human populations. The NSF is also providing support for this research.

A 3-year, $500,000 joint cooperative research project with the EPA and private industry includes utilizing unique capabilities and facilities for testing building envelope thermal materials and systems. This work is conducted at the Roof Research Center, which is a national user facility. Products are being tested to evaluate the effectiveness in reducing heat gains and losses through low-sloped commercial roofs. New materials are being identified and tested to replace products produced with CFCs. CFCs are being phased out as directed by the Montreal Protocol Agreement to reduce the risk to the ozone layer. Cooperative projects with the EPA also include a study of advanced thermodynamic cycles for refrigerator/freezers using alternate refrigerants and a laboratory and field study of foam insulation with non-CFC blowing agents.

ORNL scientists are also assisting the EPA with the development and evaluation of advanced spectroscopic methods for analyzing chemical pollutants.

ORNL scientists are evaluating and analyzing the literature and will prepare a variety of health and environmental summary and assessment reports for the EPA:

- chemical hazard information profiles,
- reportable-quantity documents for carcinogenicity and chronic toxicity,
- health- and environmental-effects documents,
- reference dose/concentration profiles for oral and inhalation exposures, and
- report on reduced uncertainty in risk assessment methodology development (less than lifetime risk assessment).

In addition to the above-mentioned types of documents, ORNL is collaborating with EPA, industry, and universities to prepare in-depth health effect evaluations on exposure to electromagnetic fields and diesel engine emissions.

Database development activities for the EPA are expected to increase. CURE, an evaluated database, is under development for the OHEA. CURE will be an on-line interactive file to be used by EPA scientists and regional offices for performing chemical risk assessment. In addition, ORNL will continue to develop a peer-reviewed Genetic-Toxicology Database and Environmental Mutagen and Teratogen Information Center Files that are pertinent to performing chemical hazard assessment and conducting quantitative structure activity relationship studies. A novel technique developed in association with the EPA's Health Effects Research Laboratory allows for the computer generation of graphic display of experimental data on single chemicals, groups of chemicals, and so on. These resources (toxicity data on more than 22,000 unique chemicals) are being used for finding patterns among chemical and biological data. This effort represents one of the largest of its kind.

Because of the reauthorization of the National Acid Precipitation Assessment Program early in FY 1991, acidic deposition research and assessment activities declined in FY 1992 but are expected to increase slightly by FY 1993. Major emphasis is on the effects of acidic precipitation on forest and aquatic systems and on ion mobility in soils. New emphasis will be placed on cost-benefit analyses of Clean Air Act–mandated emissions controls. Continued support of the EPA's critical loads research program is also anticipated.

ORNL will continue its research and analysis support to the EPA's Environmental Monitoring and Assessment Program in the areas of ecological indicators, landscape pattern analysis, biological markers, environmental risk, and technical integration and assessment. Work will also continue on the development of an environmental assessment sourcebook for the EPA Office of Federal Activities.

EPA support is expected in four important analyses dealing with ecological impacts resulting from global climate change. The project will take four approaches to the problem of predicting biospheric response to global change: (1) assemble relevant databases regarding the increase in trace gases in the atmosphere; (2) perform critical experiments regarding the direct and indirect effects of pollutants on tree species; (3) synthesize data, models, and experimental results to produce regional predictions of the direct and indirect effects of global change; and (4) simulate the global response of vegetation to climatic effects. ORNL anticipates new work with the EPA on the effects of anthropogenic stressors on habitat and biological diversity research. Habitat changes in the southeastern United States are the focus of one initiative. Another area of research is the effects of climate change and land use modifications on tropical ecosystem fauna.

Research in advanced data systems continues for the EPA's Office of Planning, Budget, and Program Management. This research will develop computer-analysis capabilities that will allow the EPA to better formulate environmental regulatory policy and to analyze groundwater-contamination problems. Although research on ecological risk of chemicals declined in FY 1990, an increase in this area is expected in 1992.

In addition, ORNL is participating in the development of the EPA's new climate change initiative and will continue to expand its work for the Office of Emergency

Response and Waste Management to help develop modern computerized information management systems in support of RCRA and CERCLA.

ORNL provides technical support to EPA Region IV programs such as restoration and remediation of sites in the southeastern United States listed on the National Priorities List. Work is ongoing to evaluate the adequacy of existing emergency-response systems in the vicinity of chemical plants. In addition, research in physiological pharmacokinetic models, which aids in low-dose extrapolation, continues for the EPA's Carcinogen Assessment Group. ORNL is also analyzing environmental issues and opinions for the Office of the Administrator.

National Science Foundation

ORNL is expecting some growth in the overall amount of funding provided by the NSF in the next several years, particularly in those areas where the Laboratory has either unique capabilities or where the basic research projects are not funded by DOE. Discussions are in progress to assist the NSF in promoting educational training for the sciences. The NSF has supported an ORNL study on the fundamental aspects of the technology for the reliable and reproducible cryopreservation of Drosophila embryos, the resolution of which will obviate the need for maintenance by continuous transfer of 10,000 mutant stocks worldwide.

ORNL has submitted a proposal to NSF to fund a postdoctoral student to interact with university users of the Small Angle Neutron Scattering Facility. Although the proposal has been well received, funds had not yet been awarded as of mid-FY 1992, and no specific start date has been established.

Because of its unique position as a leader in systems and theoretical ecology, ORNL plays a strong role in these fields and works closely with various universities. The NSF recognizes ORNL's leadership in ecosystem research and global terrestrial carbon cycling and provides support for a study of nutrient cycling, ecosystem metabolism, and ecosystem resilience. This project involves development and experimental testing of models that relate nutrient cycling in stream ecosystems to certain physical and biological characteristics of streams in order to predict the response of stream ecosystems to disturbance. ORNL will continue to explore its potential contributions to the planned interagency (U.S. Department of Interior-NSF-DOE) Continental Drilling Program. Another research effort sponsored by the NSF involves development of a fiber-optic-based fluoroimmunosensor, an instrument using monoclonal antibodies and laser-induced luminescence for the detection of trace levels of biological species in body fluids. Additional research is expected to include mathematical and statistical methods for data analysis.

ORNL is providing technical assistance to the Division of Polar Programs in their effort to evaluate the environmental impacts of U.S. activities implementing minimal-impact goals in Antarctica. ORNL has prepared a programmatic EIS on the U.S. program and will continue to support NSF in implementing minimal impact goals and preparing site- and project-specific environmental impact assessments. Emphasis is being placed on waste and fuel management, logistic support facilities, sensitive resources, and global concerns for the pristine Antarctic environment.

Federal Emergency Management Agency

DOE and its predecessor agencies have been providing major research support to the Federal Emergency Management Agency (FEMA) and its predecessor agencies for more than 35 years. Current ORNL programs for FEMA include a range of research, development, and technical assistance activities in support of national preparedness for major emergencies. At FEMA's request ORNL serves as an independent center of expertise in areas ranging from engineering assistance to analysis and assessment. Engineering work includes assisting in hardening civil defense installations against electromagnetic pulse effects, development of devices that protect against the effects of electromagnetic pulse, and testing equipment.

Analysis and assessment activities include building economic models of preparedness options, assisting with the use of computer graphics, studying human behavior in emergencies, and working on state-of-the-art assessments on various programs and issues. These activities will also include the following issues:

- development of a National Infrastructure Information System,
- emergency preparedness to hazardous material accidents including those involving chemical weapons,
- impacts of disasters,
- postdisaster economic recovery,
- data sources for emergency management,
- shelter concepts for emergency protection,
- civil defense program planning,
- evacuation planning for natural and man-made disasters,
- public alert/notification system performance,
- preparedness for special populations and institutions, and
- adequacy of training for emergency workers.

Agency for International Development

ORNL serves as a center of expertise for the Office of Energy and Infrastructure, Bureau of Research and Development, AID on (1) energy planning and policy development (EPPD) and (2) renewable energy applications (REAT). ORNL's activities include research; analysis; technical assistance; project development, implementation, and evaluation; and information dissemination. In the area of EPPD, ORNL emphasizes energy efficiency improvement, environmental management, R&D roles, institution building, and technology cooperation. In REAT, the Laboratory emphasizes biomass energy systems and rural/decentralized applications.

Through its relationship with AID's Office of Energy and Infrastructure, ORNL also supports programmatic activities in other bureaus, offices, and field missions of AID. For instance, the Laboratory is currently assisting AID's Regional Office for Central American Programs as technical monitor and project evaluator for a large multiyear rural electrification project.

Besides its continuing relationship with this one office, ORNL provides similar technical assistance directly to other parts of AID as well. One such commitment is to carry out analyses and technical assistance on environmental and natural resource management issues for AID's field mission in Guatemala.

Many citizens of developing countries use indoor combustion for cooking or space heating. AID is providing assistance to these countries in the development of fuels that emit smaller amounts of pollutants to improve indoor air quality in these countries. Research staff are evaluating the effects of additives on reducing toxic emissions from traditional Pakistani fuels. In addition, they have trained Pakistani scientists in the design of these experiments so that further development can occur in Pakistan. Future work is expected to assist fuel scientists in other developing counties.

U.S. Department of Transportation

ORNL's Center for Transportation Analysis, which receives funds from DOT, covers all transportation modes: particular attention is given to highway transportation, which accounts for more than 73% of the nation's energy used on travel. ORNL is assisting FHWA, and will assist the soon-to-be-established Bureau of Transportation Statistics, in research areas that include development of freight and passenger demand models; assessment of data quality and data consistency of highway statistics; development of data collection methods and advanced data management systems to improve data integrity and availability; analysis of nationwide surveys to address issues in current or future national transportation policies; development of methods to statistically link data sources to study intermodal traffic; and research on intelligent vehicle and highway systems.

In response to the FHWA's 1990 National Transportation Policy, research effort provided by ORNL is increasing in several areas. First, ORNL is developing procedures to estimate the private sector's contribution to the nation's highway infrastructure. Second, ORNL is assisting the FHWA to study the relationship between truck accidents, highway geometric design, and truck performance characteristics. Results from this study will guide how highways will be designed to accommodate more safely heavier trucks in the nation's highway system. Third, ORNL is developing methods to reduce statistical bias in the 1987 nationwide truck surveys: the Truck Inventory and Use Survey and the Nationwide Truck Activity and Commodity Survey. The sampling plans of these surveys will be evaluated to better plan and to implement the next surveys in 1992.

The FHWA's Highway Traffic Forecasting System has been redesigned by ORNL to provide improved forecasts of trucking activity nationwide and of the impacts of this activity (in terms of pavement loadings) on the condition of the nation's highways. Related research in highway network design is looking at possible alternative designated routing options for trucks. Improved routing will allow more economical transporting of goods across country and will reduce the potential for considerable damage to our highway system's infrastructure. More effective highway network design and routing policies can also benefit DOE because they will provide better options for the shipment of spent nuclear fuel. ORNL is helping the FHWA to examine future federal network design options, to ensure national network connectivity, and to anticipate future traffic growth.

Innovative log-linear modeling of vehicle-miles-of-travel by vehicle types, roadway class, season, and state provides the FHWA with a means of generating travel forecasts from large, sparse matrices containing large numbers of zero-valued cells. Research into the relationship between methods of forecasting vehicle-miles-of-travel and fuel use at the national level offers insights that are useful to both DOE and FHWA policy and planning staffs. ORNL is also increasingly involved in helping the FHWA select and make the best use of sampling methods for the collection and analysis of truck freight transportation information.

To support these analytical efforts, and in cooperation with agencies within DOE and DOD, ORNL has been the leader in the development of an extensive national highway network database that currently contains roadway lengths, traffic capacities, and other statistically and operationally useful planning characteristics for about 380,000 miles of highway. Workstation versions of this network data base are being developed for use in a variety of graphically enhanced highway research applications.

Other continuing work for the FHWA has produced workstation-based simulation models and associated microcomputer graphics systems to replicate and depict complex traffic-stream management strategies for congested urban street layouts. In addition, ORNL will be increasingly involved in providing the FHWA with technical support on research projects that study highway safety from the viewpoint of geometric design, highway systems operation, and hazardous materials transport. Application of expert-system methodologies to traffic-simulation problems is also emerging as a future research area.

For a National Highway Network Evaluation and Design Project, ORNL will generate a number of candidate 2020 national highway networks. Goals such as traveler mobility, equity, intercity trade, and connectivity for national security reasons will be translated into network design/selection criteria.

Working with FHWA, ORNL is developing real-time traffic monitoring and routing models. Real-time traffic analysis is a rapidly growing area of work dealing with the increasingly important issue of the energy and environmental effects that vehicle traffic may have on our cities.

ORNL will also support the FHWA's expanding research on intelligent vehicle and highway systems. This area of research holds promise for reducing congestion and highway accidents through advanced electronic traffic monitoring and control systems together with intelligent vehicles and guideways.

In addition, the Federal Aviation Administration is developing a modeling and analysis facility, the National Airsystem Management Facility, for the development of advanced systems for airport and airways management. ORNL is well suited to provide research support to this new facility, and to other operations research and simulation efforts in the Federal Aviation Administration by virtue of its extensive R&D work for MAC.

U.S. Department of the Interior, Bureau of Reclamation

A renewed interest in seawater desalination has been demonstrated in current legislation that will result in an initiative funded in the Bureau of Reclamation beginning in FY 1992. An ongoing initiative was begun in FY 1991 at ORNL to begin the fundamental work necessary to support this initiative.

U.S. Department of Commerce

ORNL is providing technical leadership in support of the Coast Watch Change Analysis Program (C-CAP). C-CAP is sponsored by the Coastal Ocean Program of the National Oceanic and Atmospheric Administration (NOAA) and administered through NOAA's Southeast Fisheries Center, National Marine Fisheries Service (NMFS). ORNL's primary responsibility is to conduct R&D on land cover monitoring in the coastal regions of the United States.

ORNL will provide planning, technical coordination, and implementation of regional projects designed to employ the C-CAP protocols in coastal regions. Each project will involve collaboration with a university, state government agency, or other regional organization. Technology transfer will be a key technical requirement in the collaborative efforts. Candidate regional projects include Galveston Bay, the Louisiana Coast, Tampa Bay, the South Carolina Coast, the North Carolina Coast, Chesapeake Bay, the Rhode Island Coast, the St. Croix Estuary, the Alaska Coast, San Francisco Bay, the Columbia River Estuary, and portions of the Great Lakes. ORNL will process satellite imagery and other data in support of these regional projects and will develop improved methods and techniques for measuring spectral change. ORNL will develop new methods and techniques appropriate to the assessment of accuracy in large spatial databases involving change over time.

Other Federal Agencies

ORNL also provides technical support to a variety of other federal agencies. ORNL anticipates collaborative work with the USDA, including the Agricultural Research Service, the U.S. Forest Service, and the USDA Research Laboratories at Beltsville, Maryland, and other sites throughout the country.

Some support to ORNL has been provided by the U.S. Department of State for work performed for the International Atomic Energy Agency and the United Nations Educational, Scientific, and Cultural Organization, and we expect this support to continue. ORNL is assisting the National Park Service in preparing an environmental report on a proposed extension of the Foothills Parkway, adjacent to the Great Smoky Mountains National Park.

Support has also been provided by the U.S. Department of Education, the U.S. Department of Justice, the U.S. Department of Labor, and TVA. ORNL is currently assisting TVA in an assessment of the potential for biomass energy within the TVA power system. ORNL provides support to the Bureau of Labor Statistics in artificial intelligence systems to provide estimation of consumer prices index and survey automation. Work is anticipated in support of the Office of National Drug Control Policy and its various support agencies.

In the area of environmental management of water resources, ORNL provides support to several additional federal agencies. For example, ORNL staff serve as technical advisors to the Bonneville Power Administration, the Bureau of Indian Affairs, and the U.S. Army Corps of Engineers on environmental issues such as hydropower impacts on fish and wildlife and instream flow policies. New work is also anticipated in FY 1992 from the U.S. Fish and Wildlife Service related to development of a Recovery Plan for threatened/endangered fish species in the Upper Colorado River Basin.

The U.S. Geological Survey (USGS) is funding new research designed to develop a network of precipitation collectors in the United States to analyze trends in trace metal wet deposition. This work is in collaboration with the USGS Central Regional Office in Denver and the State Water Survey at the University of Illinois. The ORNL work involves collection of weekly rain samples at Walker Branch Watershed for analysis of lead, cadmium, arsenic, copper, manganese, and zinc and development of new methods for collection and analysis of wet deposited mercury.

Nonfederal Organizations

Electric Power Research Institute

EPRI continues to fund research at ORNL in areas related to the generation and efficient use of environmentally acceptable electric energy. Major efforts in this area have been directed at the following issues:

- understanding the processes and mechanisms by which atmospheric deposition of energy-related pollutants affects the nutrient cycling and the sulfur and nitrogen dynamics of forest ecosystems,
- developing methods and models to quantify and predict air/surface exchange of mercury vapor and related compounds,
- developing a mechanistic and predictive forest-cycling model to address potential future impacts of atmospheric deposition,
- development of predictive models of fish population dynamics for use in assessment of impacts from steam and hydroelectric power generation,
- understanding the processes and improving predictions of the response of fish populations to environmental stress,
- developing methods for analyzing data to make and support decisions,
- preparing critical reviews of power-related issues associated with global climate change,
- exploring theoretical aspects of uncertainty, and
- obtaining new data on volatility of ammonium salts from high-temperature aqueous solutions.

The Laboratory expects to continue these and other programs for EPRI during the course of the planning cycle. ORNL has completed a major new book that synthesizes the results of the EPRI-funded Integrated Forest Study on the effects of atmospheric deposition on forest nutrient cycling. Work is continuing in the Compensation Mechanisms in Fish Population Program. In FY 1990 the program was expanded to include model R&D specific for hydroelectric projects impacts such as instream flow requirements and water-quality alterations. An anticipated activity with EPRI is the evaluation of forest response to elevated CO_2 and global climate change. A major new effort will begin soon titled "Atmosphere/Surface Exchange of Mercury." This work will be directed at understanding and modeling deposition and emission of vapor-phase compounds of mercury. In addition, a new project on the role of vegetation in remediating waste sites has begun. Also under discussion is an assessment of the sustainability and cost of biomass fuels for regional power grids.

EPRI continues to fund research at ORNL in areas related to the efficient use of electric energy. An efficiency research project currently under way is a test of full-size ice-storage systems for cooling commercial buildings. Also under consideration is a project to develop diagnostic procedures for detecting toxic by-products of power circuit breaker gases and a proposal to develop CFC replacement fluids in commercial chiller units.

In FY 1992 EPRI called upon ORNL's expertise in biomass energy to assist in analysis of the potential of biomass feedstock for electric power plants. This interaction is expected to increase in the future with new EPRI funds.

EPRI is currently cofunding development and demonstration at ORNL of intelligent control systems for nuclear power plants. This includes such topics as validation and verification guidelines for software used in digital nuclear plant control systems and development of portable software that runs on a variety of hardware platforms.

ORNL also has an expanding technology-development program for EPRI in the area of high-temperature structural design methods and fracture-assessment procedures for advanced reactors and other high-temperature power plant components. In these activities ORNL serves as EPRI's R&D arm in collaborative studies between EPRI, the Central Research Institute for Electric Power Industry in Japan, and the Central Electricity Generating Board in the United Kingdom. Results of these joint studies help to fulfill identified needs in DOE's LMR and MHTGR programs.

In addition, ORNL is researching a portable operating system for power-plant controllers. This project is proposed as an exploratory research project for EPRI involving technology acquisition that may have a significant economic impact on control system software development and implementation. The project goal is the development and demonstration of a portable, real-time operating system compatible with the UNIX operating system. The results will indicate methods to minimize or to eliminate the difficulties and expenses that a utility may encounter in transferring software between processors, as will be the case for future replacement of the computer hardware.

Assessment of the role of volatile salts such as ammonium chloride in the carryover of corrosive species in steam generator circuits is limited by the lack of data and predictive models. Experimental data are being obtained at ORNL in newly designed apparatuses. These data are then incorporated into broader thermodynamic models.

Associated with EPRI research is work being funded by the Babcock and Wilcox (B&W) Owners Group to develop an improved control system for the currently operating reactors of the B&W design. The project objectives are identification, documentation, and resolution of problem areas in the current control system, development of the optimum system configuration, exploration of technological improvements in control design methods, and provision of features that meet the expanded scope of control for the new control system. ORNL's project will be a control algorithm that will be implemented by the B&W Owners Group on a new digital control hardware. An additional anticipated activity with EPRI is R&D on thin-film materials for photovoltaic and other energy applications.

American Petroleum Institute

The American Petroleum Institute (API) supports research at ORNL to evaluate the pharmacokinetics and pharmacodynamics of benzene in humans. The work is intended to provide a better estimate of the risk of developing leukemia following exposure to low doses of benzene.

ORNL is also providing support to API in the area of global climate change by developing inventories of greenhouse gas emissions associated with petroleum product combustion. The inventories will focus on energy consumption and fugitive gas losses through production, refining, and distribution.

Other Nonfederal Organizations

ORNL performs work for several other nonfederal agencies. For example, R&D sponsored by SEMATECH addresses critical national issues related to the processing of high-density semiconductor chips. This work has emphasized the development of advanced etch technology for submicron device applications. Future anticipated activities with SEMATECH include other aspects of semiconductor processing and materials development.

Private industry has joined with ORNL to identify and to test insulation materials and products that are economically feasible, durable, and free of CFCs for increasing energy conservation in residential and commercial buildings. ORNL has entered into a cooperative research project to test convective heat losses in some types of attic insulation.

Other organizations involved with ORNL include

- the United Kingdom Atomic Energy Agency,
- the Japan Atomic Energy Research Institute,
- the Canadian Atomic Energy Commission,
- the Federal Republic of Germany Umweltbunesamt,
- the Korea Advanced Energy Research Institute,
- the International Atomic Energy Agency,
- the National Institute of Radiation Protection of Sweden,
- Harvard University,
- universities of Georgia and Maryland,
- states of California, Virginia, and Alaska,
- the Metropolitan Edison/General Public Utility,
- the Pacific Power and Light Company,
- EG&G Energy Measurements, Inc.,
- the Florida Institute of Phosphate Research,
- Battelle Laboratories,
- the General Electric Company,
- the Soap and Detergent Association,
- the National Geographic Society,
- the Center for Indoor Air Research, and
- the Gas Research Institute.

Laboratory Directed R&D Program

The principal objective of the ORNL Laboratory Directed Research and Development (LDRD) Program is to provide financial support for innovative R&D ideas that, while within the general mission of the Laboratory, have no direct programmatic funding. Such ideas could lead to productive new technical directions for the Laboratory, DOE, and the nation. The program obtains its funds from DOE through an overhead charge to all other Laboratory programs. The program operates under the authority of DOE Order 5000.4A, "Laboratory Directed Research and Development," dated April 9, 1992.

There are two major activities within the LDRD Program: the Seed Money Fund and the Director's R&D Fund. The Seed Money Fund is the continuation of the original ORNL Seed Money Program that was initiated in 1974; the Director's R&D Fund was added in 1983. The approved FY 1992 budget was $10 million for the ORNL program. The budget allocated by the ORNL Executive Committee was $9 million: $2.13 million was allocated for the Seed Money Fund, and $6.87 million was allocated for the Director's R&D Fund. This total amounts to less than 2% of the total operating budget for ORNL. Table 5.33 lists authorized funding for FY 1991–FY 1994 (projected).

LDRD projects address a variety of issues that are on the cutting edge of science and technology. For example, a Director's R&D Fund project in HASRD involves fundamental studies of Buckminster Fullerenes ("Buckyballs"), which may have important applications in rocket fuel, batteries, and superconductors (Fig. 5.32).

Proposals for Seed Money Fund projects are accepted directly from the Laboratory's scientific and technical staff (with management concurrence) at any time of the year, are peer reviewed, and are selected for funding with the assistance of a Proposal Review Committee composed of representative scientific and technical staff. The 1-year projects are generally funded at less than $100,000. Director's R&D Fund proposals are solicited from the scientific and technical staff in June and are reviewed

Table 5.33
Laboratory-directed R&D funding
($ in millions—BA)

	FISCAL YEAR			
	1991[a]	1992[b]	1993[c]	1994[c]
Total funding	9.0	10.0	10.2	12.0

[a]$7.4 million allocated.
[b]$9 million allocated.
[c]Estimated.

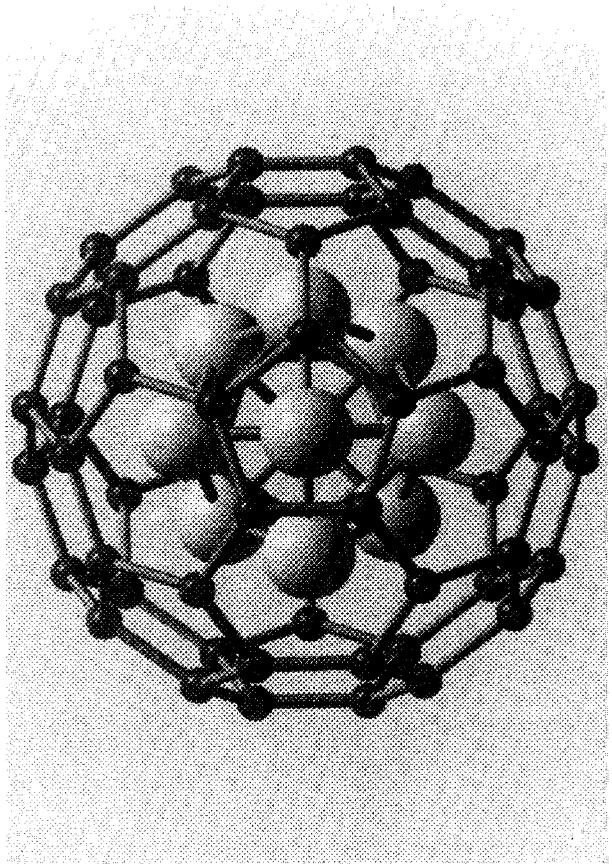


Figure 5.32
Variant of a "Buckyball," containing a smaller cluster of boron atoms within the carbon cage. The proposed structure is one of several possible structures of $C_{50}B_{10}$ that the Molecular Physics Group in HASRD has detected by mass spectrometry.

through line management; most are selected by the Laboratory's R&D Strategic Planning Committee. These projects may continue for up to 3 years at levels of $300,000 to $400,000 per year. Five to ten percent of the Director's R&D Fund is allocated individually by the Laboratory associate directors. Providing two routes of access to LDRD funds maximizes the likelihood that novel and seminal ideas originating from the staff will be recognized and supported.

Unlike the Seed Money Fund, the Director's R&D Fund is targeted at a specific list of research topics considered to be important to the future of the Laboratory. For FY 1993, for the first time, these research areas were selected by the ORNL R&D Strategic Planning Committee.

It was decided that the best approach was to choose a "focus" area, under which projects would be given top priority for funding, and several other "target" areas, from which proposals would also be considered but would have lower priority than those from the focus area. The focus area and target areas were selected by soliciting lists from members of the R&D Strategic Planning Committee of the research areas that they considered to be priorities in their respective fields. Research areas were ranked according to the frequency with which they appeared on the priority lists. Then, at a general meeting of the R&D Strategic Planning Committee, a consensus was reached on the final focus area and target areas for FY 1993.

The decision was made to limit the final list to one focus area and four target areas. They are as follows (target areas listed in no particular order):

- focus area—High-Performance Computing Applications and
- target areas— Biotechnology, Advanced Materials and Processing, Advanced Manufacturing Technologies, and Transportation.

The LDRD Program is administratively part of the ORNL Office of Planning and Management. The position of manager rotates every 2 years among members of the scientific and technical staff of the Laboratory. A study has been commissioned to evaluate the LDRD programs at each of the DOE laboratories. It should be finished by the end of FY 1992. Additional descriptions of ORNL's LDRD Program can be found in the following three DOE publications.

Accomplishments of the Oak Ridge National Laboratory Seed Money Program, DOE/ER-0274, U.S. DOE, 1986.

A Review of the Oak Ridge National Laboratory Seed Money Program, DOE/ER-0319, U.S. DOE, 1987.

A Review of the Exploratory Research and Development Programs at the Five Multiprogram Energy Laboratories, DOE/ER-0361, U.S. DOE, 1988.

The program operates efficiently and is held in high regard both internally and externally. For all divisions the overall return of new work for the Laboratory is approximately four times the program's investment. The program provides the scientific and technical staff with morale-boosting incentives to be innovative. A high percentage of honors, awards, and new programs at the Laboratory has originated through work supported by the LDRD Program.

6 Environmental, Safety, and Health Management

6 • Environmental, Safety, and Health Management

ORNL has a strong commitment to the safety and health of its people and to the protection of the environment. Management recognizes the need for improving the way environmental, safety, and health (ES&H) matters are integrated into the operation of the Laboratory. Changes in culture and organization have occurred and are permeating all aspects of operations.

A key first step is the development of a long-range ES&H strategic plan that articulates the mission, objectives, and strategies to be used. Such a document has been developed for ORNL, entitled the *ORNL Environmental, Safety & Health Management Plan* (ORNL-6702, December 1991). It is a follow-on document to the *Energy Systems Environmental, Safety & Health Strategic Plan* developed by Energy Systems and issued in June 1991. It addresses all of the components of a strategic plan, including the mission, situation analysis, objectives, and strategies.

The following is ORNL's ES&H mission statement, based both on the Energy Systems ES&H statement and ORNL's overall mission.

> The ES&H mission of ORNL is to conduct operations and R&D in a manner that protects the environment, staff, and public while allowing ORNL to continue to carry out world-class research in a competitive manner. We must achieve and maintain compliance with environmental, safety, and health laws and regulations. We intend to excel in our efforts by building an exemplary record of accomplishment in protecting the health and safety of our people and the public. We shall also be exemplary in protecting the environment from effects of present and future operations and restoring the environment from past operations. We want to become known as one of the best research laboratories in the United States in taking the lead in developing and executing innovative and cost-effective environmental, safety, and health actions.

ES&H Goals and Objectives

A set of goals and objectives has been developed for ORNL to accomplish its ES&H mission and address the issues that it faces. To a great extent, these goals are based on the Energy Systems objectives and goals outlined in the ES&H Strategic Plan. It contains 48 objectives or goals, separated between health and safety issues and environmental issues. Within each section the document identifies six categories: (1) Compliance and Excellence, (2) Personnel and Public, (3) Management Systems, (4) Cost and Productivity, (5) Technology, and (6) Facilities. Some issues apply to both environment and health and safety, causing a duplication of a number of the objectives. In addition, some issues are not addressed in the Energy Systems plan and require additional objectives and strategies in order to address them. These ORNL-specific objectives and goals are presented first and designated with an "O" in their numbering.

The objectives and goals are not commitments. It is not guaranteed that they will be achieved. The DOE *Guidelines for Strategic Planning* states the following:

> **Strategic** objectives are intended to inspire and motivate the organization to reach farther than they think they will be able to grasp. It is quite acceptable for their probability of success to be 0.5, whereas objectives in an **operational** plan must have a much higher certainty of being reached.

Achievement of objectives and goals depends on a number of variables beyond the control of ORNL and Energy Systems, the most notable being the amount of funds provided by DOE. Many, if not most, of the objectives and goals will require a commitment of resources, either directly by DOE or indirectly through sufficient programmatic efforts in order to not strain the overhead budgets. Another key variable is the likelihood that priorities will be redirected. New issues will inevitably arise that may be determined to be more important than completion of these objectives. The outcome of uncontrolled variables will require periodic reappraisal of objectives and goals to determine their expected schedules or appropriateness.

Table 6.1 provides a summary statement of each objective.

Table 6.1
ORNL ES&H goals and objectives

ORNL-specific objectives

O-1. Pursue adequate funding for ES&H activities.
O-2. Develop process to balance and prioritize R&D and ES&H aspects of work.

Health and safety objectives

Compliance and excellence

H-1. Provide a safe work environment (reduce industrial and radiation incidents to 20% of average for industry).
H-2. Achieve and maintain compliance with health and safety rules. By 1994 have no valid continuing complaints.
H-3. Conduct health and safety such that ORNL is a benchmark for other contractors by 1996.
H-4. Implement an asbestos-management program that will eliminate asbestos exposure through removal, containment, and use elimination.
H-5. Use Conduct of Operations, Maintenance, etc., to pursue excellence with emphasis on procedures, efficiency, and empowerment.
H-6. Improve ORNL understanding of customer concerns regarding safety and health.
H-7. Have health and safety staff work with line organizations in interpretation and implementation of programs.
H-8. Maintain an effective nuclear criticality safety program.

Personnel and public

H-9. Have sufficient technical personnel to support the health and safety programs.
H-10. Enhance the effectiveness of the emergency preparedness program.
H-11. Address concerns of neighbors within 24 h by senior management.

Management systems

H-12. Have more integrated and consistent systems in medical, personnel health, industrial hygiene, industrial safety, and radiation protection.

Table 6.1
(continued)

H-13. Perfect the self-assessment process for health and safety activities.
H-14. Incorporate health and safety concerns into work with other DOE contractors and subcontractors.
H-15. Have a system for identifying needs for policies and procedures based on DOE orders and other regulations.

Cost and productivity
H-16. Utilize Total Quality Management for health and safety activities.
H-17. Reduce the types and quantities of extremely hazardous substances.
H-18. Reduce the number of external and internal audits to the minimum necessary.

Technology
H-19. Structure work environments to minimize exposures and provide training and equipment for workers to be fully informed of hazards.

Facilities
H-20. Update and have approved all required safety documentation. Provide through Conduct of Operations and configuration management an integrated, compliant, and change-protected set.
H-21. By 1998 complete the phased Safety Analysis Report Upgrade Program for all facilities.
H-22. Implement a graded approach to Conduct of Operations, Maintenance, Radiation Protection, ensuring requirements are met and cost-effective activities are maintained.

Environmental objectives

Compliance and excellence
E-1. Strive to achieve and maintain compliance with environmental laws, regulations, and agreements.
E-2. Strive to achieve a minimum discharge operation.
E-3. By 2019 eliminate or reduce to prescribed levels all environmental risks from past operations through cleanup or containment.
E-4. Improve ORNL understanding of customer concerns regarding environmental compliance.
E-5. Reduce solid waste disposal to 50 and 25% of the 1991 level by 1995 and 2000 respectively.
E-6. Have the ability to dispose of low-level radioactive waste on site and/or off site by 1996.

Personnel and public
E-7. Have sufficient technical personnel to support the environmental compliance programs.
E-8. Have environmental support staff work with line organizations in interpretation and implementation of programs.
E-9. Enlist and empower all personnel in protecting the environment and in conservation and pollution protection of their workplace.
E-10. Address concerns of neighbors within 24 h by senior management.

Management systems
E-11. Help in establishing an Energy Systems–wide environmental record-keeping system.

Table 6.1
(continued)

E-12.	Maintain facility conformance with requirements through an ES&H Regulatory Compliance Assessment Program.
E-13.	Incorporate environmental concerns into the Energy Systems procurement process.
E-14.	Incorporate environmental concerns into work with other DOE contractors and subcontractors.
E-15.	Have a system for identifying needs for policies and procedures based on DOE orders and other regulations.
E-16.	Work with DOE for mutually accepted risk and vulnerability prioritization for environmental projects.
Cost and productivity	
E-17.	Utilize Total Quality Management for environmental activities.
E-18.	Shorten average time elapsed for each phase of environmental restoration projects.
E-19.	Reduce the number of external and internal audits to the minimum necessary.
Technology	
E-20.	Become the best DOE laboratory in R&D, testing, demonstrating, and transferring of new science and technologies in the environmental concerns area.
E-21.	Become the DOE model contractor for use of appropriate new technology in remediation or restoration projects.
E-22.	Continue to be asked by DOE to provide leadership in environmental restoration and waste management.
Facilities	
E-23.	Include planning for environmental compliance and pollution prevention in new projects.
E-24.	By 1992 have all permitted facilities under configuration change control.
E-25.	Minimize environmental impacts from deteriorating, inactive facilities.
E-26.	Successfully implement and operate all radioactive and mixed waste management facilities.

Current Conditions

The issues that face ORNL with regard to ES&H matters can be summarized in five main categories. These categories cover in a broad scope the majority of ES&H issues that ORNL faces. They are derived from the Energy Systems plan, the Tiger Team root causes, as well as ORNL management judgement. The issues are internally and externally driven and represent both threats to the mission and opportunities to be exploited. These are not organized in order of importance. Rather, the sections present a logical sequence, detailed in the following sections.

Increased ES&H Expectations and Regulatory Requirements

There has been an increased awareness throughout society of the need for industry to improve its management of ES&H matters. In the mid-1980s, public trust in DOE's operations eroded because of widely publicized problems within the DOE complex. It became apparent that DOE facilities needed a significant improvement in their ES&H performance. New requirements were imposed, and earlier requirements were more strictly enforced. DOE orders and Energy Systems policies have required additional reviews and documentation before many tasks can be done. These steps were necessary and have ensured that activities are appropriate and in compliance with laws and orders. However, this extra effort has significantly slowed many activities and has increased their cost.

ORNL Variances from Expectations

ORNL's past is replete with significant advances in scientific and technical knowledge, much of it in the area of nuclear science and engineering. This history has created several major present-day problems. One is that many of the facilities, the state of the art in their time, still exist and are below current-day standards for safety and health. Also, during research, development, and pilot production, operations were performed that resulted in radioactive or hazardous chemical contamination of facilities and surrounding ground. Although much of the work, including waste management, was thought adequate or even advanced at the time, the resulting waste and environmental legacies do not meet current standards. These legacies will require major amounts of restoration activities for the foreseeable future. Also, as any institution grows and matures, a work culture takes hold. A strong "cultural inertia" develops that makes it difficult to change the attitude and behavior of personnel. At ORNL, this inertia has created resistance to change in ES&H matters, especially in areas of administration and documentation, which have less-observable immediate benefits. Management has recognized the need for change and has led the effort to institute a new attitude throughout the organization. ORNL's goal is to comply with ES&H requirements as rapidly as it is possible for us to do so.

Inadequate Resources To Fully Satisfy Expectations

At the same time that DOE was rapidly increasing its ES&H requirements, it was faced with overall budgets that did not keep pace with these requirements. Budgets were prepared and approved long before the new ES&H requirements were set and the associated costs were known. Researchers did not include sufficient funds for ES&H in their proposals. When needs increased, overhead rates on research accounts were raised or research funds were redirected to pay for the increased requirements, or necessary actions were deferred.

These strategies have had several negative effects. There has been a net decline in support for basic science at ORNL. Often, funds have not been budgeted for facility maintenance or complete cleanup afterwards. As a result, facilities have deteriorated and require costly repairs and upgrades for continued use. Also, a large number of "orphan facilities" remain that have no current sponsor but for various reasons will not be accepted into the surplus facility program. There are numerous areas where funding has not been sufficient to upgrade ORNL's ES&H compliance posture. The support cost is beyond the means of ongoing research activities or overhead. Many ES&H categories require a substantial infusion to bring them to a point of compliance where ordinary programmatic and overhead charges will suffice to maintain the compliance status.

Even if adequate funding were available, there would be difficulty in finding sufficient numbers of personnel with critical ES&H skills. This lack of trained personnel is a national problem resulting from the recent explosion in regulatory requirements. DOE and its contractors are harder hit by this shortage because of the recentness of their needs, the work environment, and the pay scales that can be offered.

Insufficient Management Systems To Meet Expectations Effectively

Management systems, while evolving to meet the increased ES&H emphasis, need further improvement. Key weaknesses are in the areas of diversity of operational practices, inefficient corrective action management, unclear roles and responsibilities in ES&H

matters, and immature institutionalized self-assessment. These weaknesses have been recognized by senior ORNL management and are being addressed.

The relative autonomy of divisions, programs, and other research groups is appropriate for a multifaceted research organization but does not correspond to the organizational structure with which DOE and other regulatory groups are most familiar. Auditors have frequently noted that there are excellent responses in many places in the Laboratory, but less so in others. The question is how to improve the consistency of response across the Laboratory without imposing inappropriate controls on research.

When resources are insufficient to do everything that is necessary, there must be a system that ensures that the most important activities are addressed and corrected. A prioritization system has been utilized to allow comparison of the relative importance between activities. Further work is necessary to provide efficient and timely communication of requirements, assign responsibilities, and monitor performance.

There are two aspects of ES&H central staff functions at the Laboratory: (1) assistance and guidance to line staff who must organize their research and other functions to comply with ES&H requirements and (2) internal appraisals and audits to exert management control to ensure that the requirements are met. Managing these functions to avoid conflicts of interest yet maintain a common understanding of the requirements is difficult with limited resources and an inadequate number of skilled personnel. In the past, responsibilities for compliance with ES&H regulations were generally assumed by the ES&H organization because of their expertise in the area and the willingness of line management to transfer that responsibility. Recently line managers have taken an increased role in the ES&H aspects of their work.

Senior management is striving to make self-assessment against high standards of ES&H compliance a part of the ORNL culture. The process should incorporate division-level identification of problems and proposals for correction. It should also be capable of Laboratory-wide integration to identify generic and cross-division issues. Components must be in keeping with DOE directives on the subject and must include provisions for independent assessment as well. Such a process is only beginning to be implemented at ORNL and must be more fully integrated into the operations of the Laboratory.

ORNL's National Leadership in ES&H Matters

At ORNL many areas exist for improvement in ES&H matters; however, some unique capabilities also exist for which ORNL is nationally recognized. Several of ORNL's divisions perform world-class research in various environmental fields (Environmental Sciences, Health and Safety Research, Analytical Chemistry). The safety and health programs and Conduct of Operations of other divisions have become models for other DOE organizations. Within the DOE system the Research Reactor Division is a leader in safe and productive research reactor operation. The Waste R&D Program conducts worldwide research on improvements in the handling of waste and the remediation and restoration of waste sites. Overall, ORNL is considered one of the best run of the DOE laboratories in the ES&H arena.

ES&H Policies, Organization, and Management

The organizational structure of the Laboratory has evolved over the years along with its evolving R&D missions. Changes have been made to enable ORNL to respond more effectively to challenges arising from ES&H issues. These include the creation of a directorate for ES&H compliance and the creation of the ES&H Coordination Committee. This committee was formed to provide better communication and coordination of tasks among organizations involved in ES&H activities. It is chaired by the ORNL deputy director and consists of senior ES&H managers, six members of the ORNL Executive Committee, and the chairman of the Division/Program/Office Directors' Caucus, thereby providing top-level management overview of this vital area.

Most ES&H and quality assurance (QA) functions at ORNL have been combined into one organization, strengthening the ability both to audit and to assist the divisions in their ES&H and QA activities. This organizational change has enhanced communication between the ES&H groups and has improved the accountability of each group for the performance of its functions. Also, this change moved the ES&H function from several division-level groups to one group whose director, a member of the Executive Committee, reports to the Laboratory director. The ES&H functions related to general plant operations, such as waste management and fire protection, are located within the Operations Directorate. Figure 6.1 shows the key elements in ES&H management.

The ES&H Compliance (ES&HC) Directorate consists of five offices, one department, and three programs. The offices are Environmental Compliance and Documentation, Operational Readiness and Facility Safety, Radiation Protection, Safety and Health Protection, and Quality Programs and Inspection. Each of these offices directs the oversight and support of a different facet of compliance and improvement in the operations of ORNL. The Special Projects Program coordinates the DOE-wide Safety and Health five-year planning process for the Assistant Secretary for Environment, Safety, and Health. A second program is a coordinated Energy Systems Groundwater Program for all sites managed by Energy Systems. A third program coordinates the Tennessee Oversight Agreement signed by DOE and the state of Tennessee, which allows state environmental inspectors access to all areas of the Laboratory.

Most of the remaining functions that are typically considered as being related to ES&H activities are within the Operations Directorate. This includes the Health Division, Laboratory Protection Division, and the Waste Management and Remedial Action Division (WMRAD). The Plant and Equipment (P&E) Division and the Training and Development Department within the Human Resources Division also have aspects of their work that are related to ES&H activities.

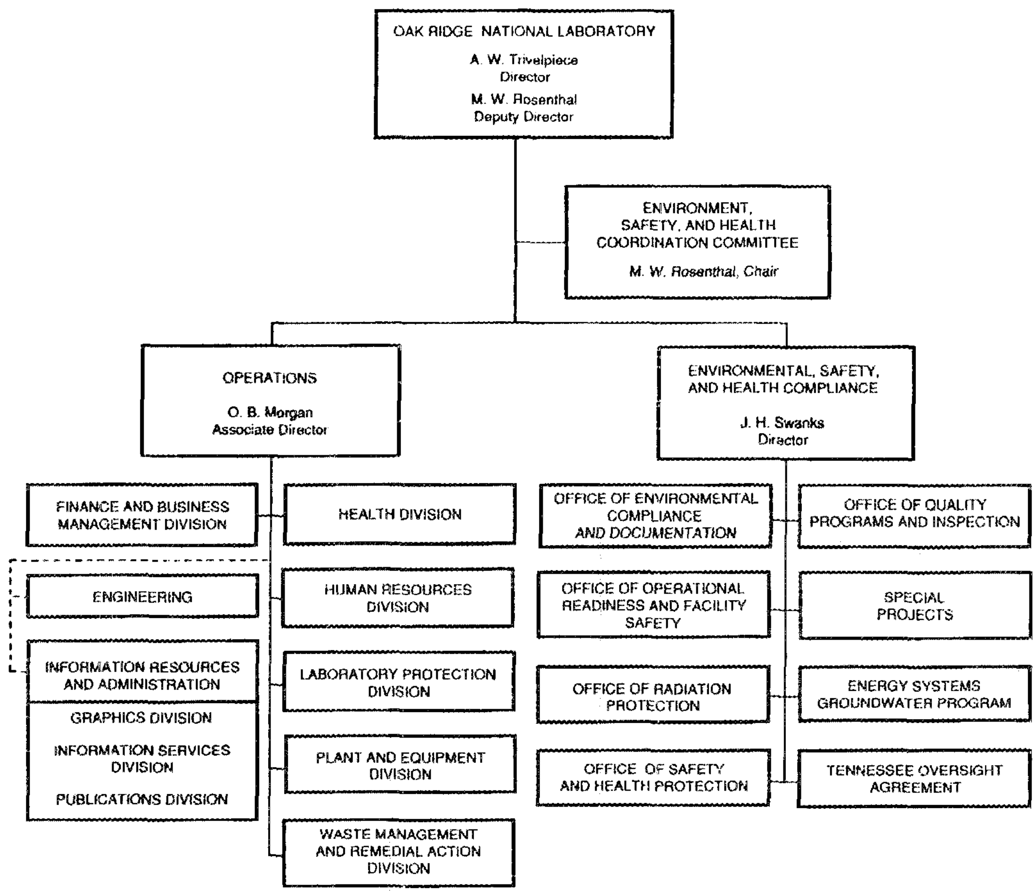


Figure 6.1
Key elements in ES&H and QA management and support divisions' management

Although the ORNL central ES&H and operations organizations provide much of the support for ES&H activities, the research divisions, as line organizations, are responsible for the ES&H activities within their areas. Divisions are responsible for having all of their personnel properly trained for the functions they perform, ensuring that their facilities are safe and in compliance and that problems or issues that arise are addressed in a reasonable manner.

Each division has several ES&H offices held by members of the division. These positions can be part- or full-time and include the division safety officer, the radiation control officer, the environmental protection officer, and the training coordinator. There are other, more specialized positions as well, such as the hazardous communications coordinator, quality assurance coordinator, and waste minimization coordinator. Some ORNL divisions have consolidated the above offices into a single section within the division that is staffed by full-time personnel to provide line-managed support for ES&H within the division. The majority of divisions have a quality assurance specialist who is a member of the Office of Quality Programs and Inspection, located with the division for assistance and oversight.

Facility managers have been designated for each facility or area within the Laboratory. These people have responsibility for the activities occurring within their assigned area. If any work is to be performed that may affect the health or safety of the personnel, the facility manager is to approve it beforehand. This greatly increases the sense of ownership that divisions have in their facilities and leads to more active implementation of ES&H measures.

Research divisions, as line organizations, are responsible for implementation of ES&H requirements in all of their activities. This requires attention in all steps for accomplishment of a mission: planning, scheduling, budgeting, training, implementation, and monitoring. Division directors and their staff work with the support organizations to ensure that ES&H requirements are properly included. Some divisions utilize a more formal system than others, depending largely on the levels of hazards involved. All divisions are increasing their efforts in self-assessment, evaluating their operations and facilities to determine possible deficiencies and areas that need improvement.

Management and performance indicators are published monthly. These indicators receive a wide distribution to Laboratory management and are also distributed to Energy Systems and the DOE Site Office. The indicators cover a wide range of subjects such as personnel exposures, corrective and preventative maintenance, waste management issues, environmental (RCRA, NEPA) issues, audit and corrective action status, occurrence reporting and report status, and an assortment of administrative and safety concerns. The indicators also include trending, lessons learned, and alerts as well as milestone and TQM implementation status. The data are used by managers to identify positive and negative trends and to react proactively.

ES&H Plans and Initiatives

Strategies have been developed for addressing each of the ORNL ES&H objectives. These strategies detail the actions necessary to achieve the objectives. In addition to these strategies are numerous program, compliance, and audit response plans that provide guidance in other ES&H activities that are necessary for the continued operation of the Laboratory but that do not relate specifically to the stated ES&H goals and objectives. Figure 6.2 shows the relationships between the major types of plans. Typically there would be a flow down of direction between plans; there can also be a flow of information up. In addition, a significant amount of crossflow of information takes place between corrective action plans, program plans, and compliance plans.

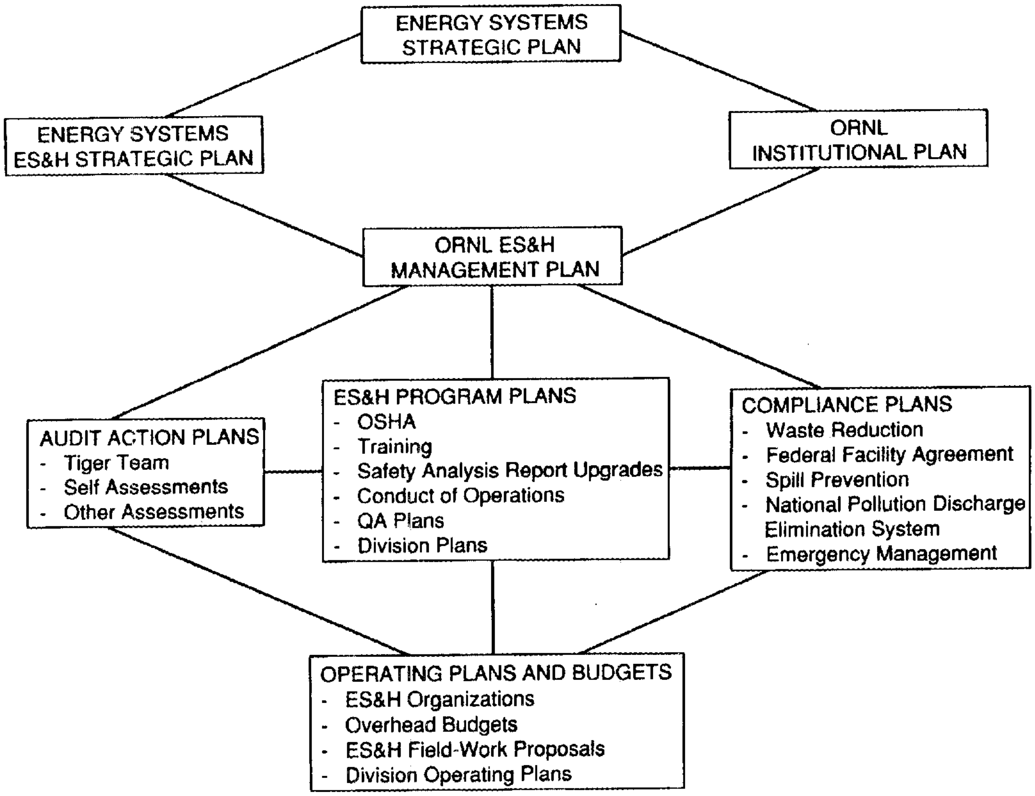


Figure 6.2
Relationships among ES&H planning documents

Table 6.2 provides the estimated cost of safety and health (S&H) for ORNL based on the input to the DOE Safety and Health Five-Year Plan. These costs were developed through analysis of the expected needs at the Laboratory and are divided into three groups: Core, Compliance, and Improvement. Actual funding for future years has not been determined. All activities associated with these costs have been ranked using the DOE S&H Risk Prority Matrix, and the results have been submitted to DOE-OR for transfer to the responsible primary secretarial offices. In future years budgets are to be determined based on the input of the Five-Year Plan, the relative priority of individual activities, and the availability of funds. Table 6.3 shows the FTEs associated with the costs shown in Table 6.2.

Table 6.4 provides a current estimate of funding requirements associated with the ORNL Tiger Team Assessment. Because many of the corrective actions are being performed as part of an individual's ordinary duties, it is difficult to completely capture all associated costs. This is especially true for actions funded indirectly through overhead rather than as specific requests to DOE. As can be seen, there is still a significant amount of funds required to complete the actions in response to the Tiger Team.

The role of the Waste Reduction Program (WRP) is to provide coordination and technical guidance to divisions in the reduction of waste, as well as the planning and reporting that is required by state and federal laws and DOE orders. Additionally, waste streams that are common to several divisions are evaluated by the WRP. The WRP addresses all waste streams generated at ORNL: sanitary/industrial, radioactive, hazardous, and mixed. The Pollution Prevention Awareness Program is also administered by WRP and is designed to heighten employee awareness of the waste reduction initiative and to emphasize the value of each individual's contribution toward reducing waste. Table 6.5 provides the funding requirements for the Waste Minimization Plan.

Table 6.2

Safety and Health funding requirements[a,b]

($ in thousands)

	FISCAL YEAR						
	1992	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Indirect	45,910	66,795	72,692	75,695	78,189	80,775	83,471
Operating[c]							
Conserv. & renewable	42	44	48	52	53	54	56
Defense programs	900	1,460	1,130	990	980	920	870
ER/WM[d]	11,975	13,962	14,241	14,761	14,575	15,198	15,836
Energy research	35,095	80,263	103,917	94,594	89,213	87,670	82,802
Nuclear energy	13,135	24,942	30,599	2,864	2,129	2,193	2,263
Total operating	61,147	120,671	149,935	113,261	106,950	106,035	101,827
Capital equipment							
ER/WM	600	2,000	1,450	500	600	600	400
Energy research	3,497	11,277	11,362	8,934	9,557	9,699	9,603
Nuclear energy	275	400	0	0	0	0	0
Total capital	4,372	13,677	12,812	9,434	10,157	10,299	10,003
GPP[e]							
ER/WM	0	150	1,350	250	0	0	0
Energy research	2,300	870	4,330	2,550	0	0	0
Total GPP	2,300	1,020	5,680	2,800	0	0	0
Line item							
Defense programs	0	0	0	0	9,750	20,500	9,900
ER/WM	0	1,100	3,000	12,800	10,200	10,200	0
Energy research	100	1,000	4,800	18,900	12,300	12,000	17,000
Total line items	100	2,100	7,800	31,700	32,250	42,700	26,900
Total Safety & Health	**113,829**	**204,263**	**248,919**	**232,890**	**227,546**	**239,809**	**222,201**

[a]Does not include cost from central organizations distributed to ORNL.
[b]FY 1991 not available because these data are based on the Safety and Health Five-Year Plan, which only required data from FY 1992 to FY 1998.
[c]Includes division administration as a direct operating expense.
[d]Environmental restoration/waste management.
[e]General plant project.

Table 6.3

Safety and Health personnel requirements[a,b]

[Full-time equivalents(FTEs)]

	FISCAL YEAR						
	1992	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Indirect	639.1	685.8	710.2	727.7	735.7	738.7	742.7
Operating[c]							
Conserv. & renewable	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Defense programs	6.9	10.5	8.1	5.5	5.5	4.0	2.0
ER/WM[d]	54.7	60.0	59.0	59.3	58.3	58.4	58.5
Energy research	256.6	430.5	465.9	473.6	445.1	441.8	442.1
Nuclear energy	16.2	14.6	15.6	14.4	10.4	10.4	10.4
Total operating	334.9	516.1	549.1	553.3	519.8	515.1	513.5
Total Safety & Health	**974.0**	**1201.9**	**1260.0**	**1281.0**	**1255.5**	**1253.8**	**1256.2**

[a]Does not include cost from central organizations distributed to ORNL.
[b]FY 1991 not available because these data are based on the Safety and Health Five-Year Plan, which only required data from FY 1992 to FY 1998.
[c]Includes division administration as a direct operating expense.
[d]Environmental restoration /waste management.

Table 6.4
***Tiger Team corrective action plan projected funding requirements*[a]**

	FISCAL YEAR				
	1992	**1993**	**1994**	**1995**	**Beyond**
DOE-ER					
Program	11,348	11,094	9,274	740	0
GPP[b]	2,595	6,410	1,000	1,000	0
GPE[c]	40	200	0	0	0
Line item	3,338	25,915	21,000	27,200	9,400
DOE-EM					
Program	50,163	52,432	46,265	46,799	89,668
GPP	9,650	4,400	4,000	4,000	4,000
Line item	4,647	15,900	26,500	39,100	35,000
DOE-NE					
Program	30	180	400	150	50
DOE-DP					
Program	102	90	0	0	0
Overhead	3,929	1,905	365	123	77
Total	**85,842**	**118,526**	**108,804**	**119,112**	**138,195**

[a]Costs for actions are not specifically tracked within the ORNL accounting system, and funds have not been specifically requested but are included within normal budget requests. Actual funds received have not approached these amounts.
[b]General plant project.
[c]General-purpose equipment.

ORNL is in the forefront of DOE facilities in the application of the NEPA process for its planning activities. A system has been developed that helps Laboratory staff flag projects for review to determine the applicability of NEPA. Preliminary screening identifies whether projects may qualify for a categorical exclusion or may require more detailed environmental assessments. Project managers are kept informed of the status of their projects and a dedicated staff is utilized in preparing and tracking the necessary documentation. As required, only DOE personnel can make a determination on the proper classification of projects and must approve all projects, but the efforts of the ORNL staff greatly facilitate the actions of DOE.

Although there is currently a serious shortage of adequate space for ES&H personnel, as well as other ORNL staff, some relief is proposed through the new 50,000-ft^2 ES&H Compliance and Training Building (Fig. 6.3). It will house about 200 personnel from the various ES&H disciplines and will provide consolidated office space for them to interact and operate more effectively and efficiently. The 2-year project is currently scheduled to begin in 1994 and to cost $11.6 million.

Table 6.5
Waste minimization funding requirements[a]
($ in millions–BA)
Waste minimization (ADS[b] *355 & 356)*

	FISCAL YEAR							
	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
EW30–Waste Minimization (ADS 355)								
Operating	0.1	0.4	1.6	0.0	0.4	0.4	0.4	0.4
Capital equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GPP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Line items	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**0.1**	**0.4**	**1.6**	**0.0**	**0.4**	**0.4**	**0.4**	**0.4**
EX30–Waste Minimization (ADS 356)								
Operating	0.2	0.7	1.4	2.5	1.5	2.3	2.4	0.4
Capital equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GPP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Line items	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**0.2**	**0.7**	**1.4**	**2.5**	**1.5**	**2.3**	**2.4**	**0.4**
Summary (Waste Minimization EW&EX)								
Operating	0.3	1.1	3.0	2.5	1.9	2.7	2.8	0.8
Capital equiment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GPP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Line items	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**0.3**	**1.1**	**3.0**	**2.5**	**1.9**	**2.7**	**2.8**	**0.8**

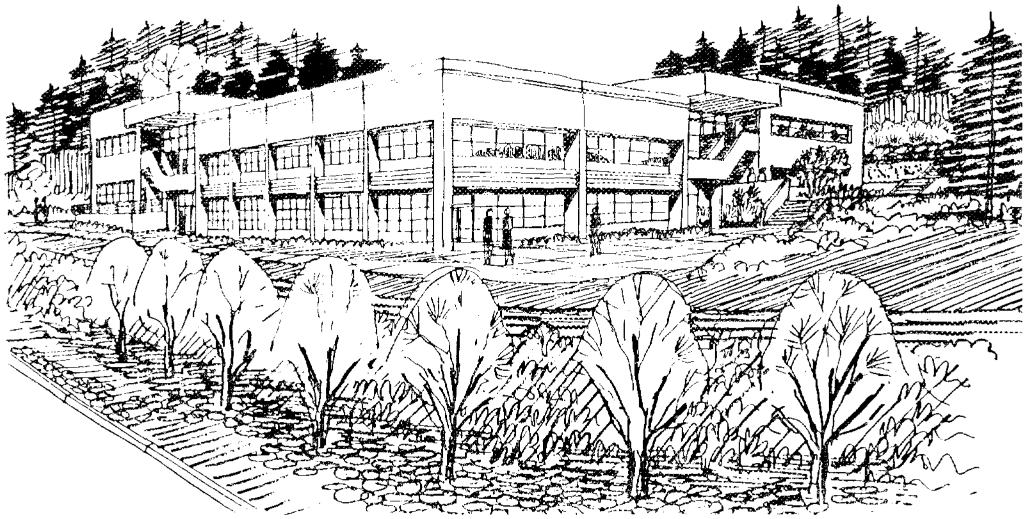
[a]Waste minimization funding is included in the WM costs in Table 6.6.
[b]Activity data sheet.

Environmental Restoration and Waste Management Activities

Waste Management

WM activities and surplus facilities management aspects of environmental restoration (ER) are managed at ORNL by WMRAD under the associate director for Operations (Fig. 6.1). Site characterization and remediation aspects of ER for ORNL are managed by

Figure 6.3 The proposed ES&H Compliance and Training Building will provide consolidated space for ES&H personnel to interact and operate more effectively and efficiently.



the central Environmental Restoration Division, which serves as the focal point for these activities at all Energy Systems installations.

The diversity of ORNL's programs and the complement of unique research facilities that support these activities present equally diverse environmental, WM, and safety and health protection challenges. Control and treatment of waste streams from the ORNL facilities have been continuing responsibilities of DOE and its managing site contractors since the beginning of Laboratory operations. WM and remedial actions are complicated at ORNL by unfavorable environmental conditions, including high seasonal rainfall, the shallow groundwater table, elevated levels of calcium and magnesium in groundwater, and complex hydrogeology.

The major sources of wastes have been radioisotope production, experimental reactors, hot cells and pilot plants (chemical separations or fuel reprocessing), research (physical, chemical, and biological), accelerators, and analytical laboratories. Solid wastes from other sites contributed a large fraction of both the material and the radioactivity buried in solid waste storage areas between 1955 and 1963; during this time ORNL served as the Southern Regional Burial Ground of the Atomic Energy Commission. A number of ORNL sites are known or suspected to contain buried transuranic (TRU) wastes; however, site radionuclide inventories appear to be dominated by fission products (e.g., ^{90}Sr and ^{137}Cs), tritium, and activation products (e.g., ^{60}Co) rather than by TRU (or uranium) wastes.

In 1985 ORNL created the Environmental Restoration and Facilities Upgrade Program to improve WM and ER, to enhance regulatory compliance capabilities, and to provide comprehensive long-range planning. Energy Systems has established a central ER Division, a central WM Division, and a central D&D Program with reservationwide management and oversight responsibilities. At ORNL, WMRAD has responsibility for WM and surplus facilities as well as D&D activities. Programmatic policy, direction, and funding are provided through the Energy Systems WM and ER divisions.

As indicated by the WMRAD title, these responsibilities are grouped organizationally into the following two functions: (1) WM functions that include responsibility for operation of all WM facilities at ORNL (with the exception of the sanitary sewage system, which is operated by the Plant and Equipment Division), corrective activities for bringing WM facilities into compliance, and facility upgrades and construction of new WM facilities; and (2) remedial action functions that cover S&M of inactive waste sites, S&M of surplus radioactively contaminated facilities, and D&D of the contaminated facilities. This general organizational grouping is consistent with the organizational structure that has been adopted by DOE-HQ, DOE-OR, and Energy Systems.

The mission of the WM function is to fully manage wastes for the purpose of protecting human health and safety and the environment. In implementing this mission, ORNL must minimize future generation of wastes, and WM operations must be conducted in a technically sound, economical, publicly acceptable, compliant, and safe manner. Major activities include comprehensive coordination of waste reduction; planning; upgrading or construction of new facilities; waste collection; certification; and treatment, storage, and disposal. The WM component manages radioactive (low-level as well as TRU), hazardous, mixed radioactive and hazardous, medical/infectious, and solid sanitary/industrial wastes. Waste forms include gases, liquids, sludges, and solids. The WM function operates 34 facilities at the Laboratory. Table 6.6 provides the planned funding for WM activities.

Funding for WM activities has increased steadily since FY 1985. Expense funding has grown from about $3.5 million in FY 1985 to about $28 million in FY 1991 for WM functions including corrective activities. Expected expense funding in FY 1992 is about $37 million, which includes $1.1 million for waste minimization (see Table 6.5). The corrective activities components of WM expense funding provide for implementation of FFA requirements as they pertain to the ORNL active LLLW tanks and tank systems. It also includes upgrades of the Bethel Valley and Melton Valley LLLW collection and transfer systems. In addition, capital funding [line item (LI)] and GPPs funding for FY 1985 through FY 1991 have been available at a level of about $13 million annually. These funding levels have provided the basis for continuing long-range planning as well as several important WM facility upgrades that include the Nonradiological Wastewater Treatment Plant, which was constructed at a cost of $18 million. This plant achieved compliance operation in March 1990.

Two important activities associated with management of LLLW include an aggressive waste minimization campaign that resulted in reduction of the LLLW generation rate by about 60% during the period FY 1985–FY 1990 and the solidification of about 47,500 gal of LLLW during FY 1989. ORNL has successfully adapted the tumulus approach for disposal of solid low-level waste, has completed a demonstration of this technology, and has begun the transition to a fully performance-based disposal system for solid low-level waste. These and many other ongoing and planned projects and activities typify ORNL WM accomplishments during the past several years.

The ORNL WM Program provides continuous collection, treatment, and discharge of gaseous wastes; treats 150 million gal/year of liquid radioactive wastes (not including sewage); and manages about 750,000 ft^3/year of solid radioactive, hazardous, mixed and sanitary/industrial wastes. The Federal Facility Agreement requirements for active LLLW tank systems are being implemented. WM GPPs for treatment, storage, and disposal upgrades are provided. Line item projects include three for implementation of the active LLLW tank systems requirements of the FFA and one each for construction of the Melton Valley Storage Tanks Capacity Increase Project (MVST-CIP) and the Process Waste Treatment Facility.

The MVST-CIP is needed because the transuranic Waste Handling and Packaging Plant (WHPP) has been deferred. The WHPP has been designed to mobilize and treat MVST liquids and sludges, treat newly generated LLLW to meet RCRA Land Disposal Regulations (LDRs); and eventually to retrieve, characterize, repackage, certify, and prepare solid TRU wastes for transport (including solidified LLLW) to DOE's Waste Isolation Pilot Plant (WIPP) in New Mexico. Outyear (FY 1995–FY 1998) activities in WM include continued operation of waste treatment, storage, and disposal facilities with many major upgrades. Waste reduction will continue to be emphasized.

TRU waste plans still are to treat and store for eventual shipment to WIPP. Additional reservation-wide WM facilities will be added to promote efficiency and improved ES&H conditions. Tables 6.6 and 6.7 show funding and personnel by EM for WM activities respectively.

Environmental Restoration

The ORNL ER Program addresses the cleanup of environmental contamination resulting primarily from past waste management practices. A wide variety of liquid and solid wastes, primarily radioactive or mixed wastes, has been disposed of on site; 300 contaminated sites have been identified on the 2900-acre ORNL area.

Table 6.6
Waste management planned funding[a]
($ in millions—BA)

	FISCAL YEAR							
	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
EM Corrective Activities (EW+EX)								
OP[b]	1.4	5.0	0.5	1.0	1.1	0.5	0.5	0.0
CE[c]	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0
GPP[d]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LI[e]	7.1	5.5	15.9	18.0	26.1	6.0	0.5	0.0
Total	**8.5**	**11.6**	**16.4**	**19.0**	**27.2**	**6.5**	**1.0**	**0.0**
Waste Management (EW+EX)								
OP	26.8	31.1	59.8	66.7	63.3	70.7	70.7	80.8
CE	2.3	4.6	5.9	1.6	2.5	3.3	3.3	2.1
GPP	10.8	14.2	21.8	7.5	9.9	14.7	11.8	7.8
LI	0.0	0.0	2.0	23.3	41.5	29.5	38.1	55.3
Total	**39.9**	**49.9**	**89.5**	**99.1**	**117.2**	**118.2**	**123.9**	**146.0**
Summary (CA+WM)								
OP	28.2	36.1	60.3	67.7	64.4	71.2	71.2	80.8
CE	2.3	5.7	5.9	1.6	2.5	3.3	3.3	2.1
GPP	10.8	14.2	21.8	7.5	9.9	14.7	11.8	7.8
LI	7.1	5.5	17.9	41.3	67.6	35.5	38.6	55.3
Total	**48.4**	**61.5**	**105.9**	**118.1**	**144.4**	**124.7**	**124.9**	**146.0**

[a]Includes Defense (EW) and Non-Defense (EX) funding for waste management functions.
[b]Operating expense.
[c]Capital equipment.
[d]General plant project.
[e]Line item.

Past R&D and waste management activities at ORNL have produced a significant number of surplus, inactive facilities contaminated with low-level radioactive and/or hazardous chemical wastes. Such sites include solid waste storage areas, waste ponds and seepage pits, radioactive waste-processing and transfer facilities, research laboratories, dedicated environmental research areas, experimental reactors, radioisotope development facilities, and the areas surrounding these sites.

Implementation of the ORNL ER Program begins with identification of sites requiring corrective actions and will end with final certification of site closure remediation or decommissioning activities. Between these two milestones is a structured path of program planning, site characterizations, alternatives assessments, continued S&M, and necessary interim corrective measures (ICMs). Some of these activities will be accomplished over relatively short time frames, while others may extend for many years. The path that will be chosen for each site depends on several variables, including site characteristics, site-specific regulatory requirements, and resource availability.

The ORNL ER Program has been divided into three major tasks: assessment, remediation, and D&D. Assessment includes identification, preliminary inspection, and

Table 6.7
Waste management personnel
[full-time equivalents (FTEs)]

	FISCAL YEAR							
	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
EM Corrective Action								
Technical	14.4	27.2	6.7	11.8	13.8	5.2	2.0	0.0
Other direct	7.4	13.6	3.3	6.0	7.0	2.6	1.0	0.0
Total	**21.8**	**40.8**	**10.0**	**17.8**	**20.8**	**7.8**	**3.0**	**0.0**
Waste Management								
Technical	93.5	143.2	238.1	246.0	220.4	234.2	233.4	226.9
Other direct	23.5	71.6	119.0	123.0	110.2	117.1	116.7	113.5
Total	**117.0**	**214.8**	**357.1**	**369.0**	**330.6**	**351.3**	**350.1**	**340.4**
Summary (CA+WM)								
Technical	107.9	170.4	244.8	257.8	234.2	239.4	235.4	226.9
Other direct	30.9	85.2	122.3	129.0	117.2	119.7	117.7	113.5
Total	**138.8**	**255.6**	**367.1**	**386.8**	**351.4**	**359.1**	**353.1**	**340.4**

characterization of sites; evaluation and selection of associated cleanup alternatives; and the preparation of decision documents. Remediation includes design and implementation of cleanup actions and remediation of inactive LLLW tank contents. D&D includes assessment and cleanup activities associated with surplus facilities not governed by RCRA or CERCLA.

Because of the large number of sites to be considered and the hydrogeologic complexity of the ORNL area, the remedial action strategy is oriented toward waste area groupings (WAGs). The ORNL sites have been placed within 20 such groupings, defined by watersheds that contain contiguous and similar remedial action sites, each representing distinct small drainage areas within which similar contaminants were introduced.

Major activities planned for FY 1993 and FY 1994 include

- continued S&M at contaminated sites, with scoping surveys being conducted at high-priority sites,
- continuation of a comprehensive site monitoring program,
- continuation of the WAG 1 Phase II Remedial Investigation (RI),
- completion of the WAG 10 Phase I RI field activities and the WAG 5 Phase I RI Report, and
- initiation of the Phase I RI for WAGs 4 and 7.

Major closure activities include

- continuation of WAG 11 contaminated debris removal and WAG 13 cesium plot ICM construction;
- completion of interim record of decisions for the WAG 1 and WAG 8 ponds, WAG 11 contaminated soil, and North and South Tank Farms ICMs;
- preliminary planning for the WAGs 4 and 5 seeps ICM and WAG 10 well plugging and abandonment;
- continued development of the WAG 7 Pit #1 ICM;
- LLLW tanks contents removal;

- removal of one LLLW tank;
- continued tank contents treatability studies;
- preliminary planning for WAGs 1 and 5 final site remediation; and
- completion of support facilities construction, site remediation design, and initiation of site remediation for WAG 6.

The ORNL D&D Program began in 1976. S&M has been conducted to ensure protection of employees and the public and the containment of contaminants. ORNL has successfully decommissioned a number of facilities under this program. Typically, these projects have been small isolated jobs such as cleanup of an intermediate waste line spill site, decommissioning of a radiochemical waste system and a curium source fabrication facility, removal of research-related facilities, and the decontamination and removal of an isotopes-storage garden.

The annual budget for S&M is about $3 million. The objectives of the S&M Program are (1) to ensure adequate containment of residual radioactive and hazardous materials, (2) to provide safety and security controls to minimize potential hazards to on-site personnel and the general public, and (3) to cost-effectively manage surplus sites and facilities in compliance with all applicable DOE orders and ES&H regulations. These objectives are met through a structured program of periodic surveillance and site inspections, routine maintenance, and special projects beyond a routine nature to correct facility degradation or to eliminate facility-specific hazards.

The budget for decommissioning of surplus facilities is highly variable and is subject to annual reprioritization by DOE. D&D projects are implemented according to priorities set at the national level by the DOE-HQ ER Program. Budget requests for decommissioning of prioritized facilities at ORNL are submitted annually and are included in the DOE Environmental Restoration and Waste Management Five-Year Plan. These priorities are then ranked with facilities and sites from other DOE installations, and budgets are allocated accordingly. Projects are then implemented by the ORNL RAP in accordance with these budget allocations.

A significant number of facilities at ORNL have been declared surplus because the programs for which they were built have been completed. Because the potential for release of radioactivity to the environment exists, facilities will undergo D&D during the next several years. Until the decommissioning operation is complete, those facilities that contain substantial amounts of residual radioactive material must be kept under surveillance to schedule any necessary maintenance and to ensure containment. The inventory of surplus contaminated facilities includes experimental reactors, technology support facilities, hot cells, isotope-processing facilities, research laboratories, and decontamination facilities. To meet the objective of adequate containment and site control, a structured program of S&M has been established to manage all activities collectively relating to surplus contaminated sites and facilities.

There are currently 101 inactive surplus facilities, including former solid waste storage areas, waste ponds, and seepage pits; radioactive waste-processing and transfer facilities; research laboratories; dedicated environmental research sites; experimental reactors; and radioisotope development facilities. A facility manager has been designated for each. The WMRAD Remedial Action Section is responsible for S&M of all areas and D&D of the contaminated facilities. Table 6.8 provides ER funding requirements for those ER elements that appear in the ORNL Financial Plan.

Landlord-Funded ES&H

As shown in the first row of Table 6.2, the indirect (overhead) funding requirements for S&H for FY 1993 ($66.8 million) is 45% higher than FY 1992 ($45.9 million). (Note that these values do not include environmental compliance costs of approximately $7 million.) During the S&H Five-Year Plan preparation, managers were also requested to identify how much of the FY 1993 funding requirements they actually expected to receive. This amount, $48.8 million, represents an increase of only 6.3% from 1992 and a 27%

Table 6.8
Environmental Restoration funding requirements, EM 5-Year Plan
($ in millions—BA)[a]

	FISCAL YEAR							
	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
EW20—Isotope Facility Shutdown Program	8.6	0	0	0	0	0	0	0
EX20—Isotope Facility Shutdown Program	5.2	12.5	22.5	0	0	0	0	0
Total EX	**13.8**	**12.5**	**22.5**	**0**	**0**	**0**	**0**	**0**

[a]Reflects funding in ORNL Financial Plan and not total ER/WM funds for Energy Systems.

shortfall from the required amount. Since the development of the Five-Year Plan, target overhead budgets have been proposed that actually reduce the overhead spending by about 5%. This is necessary because of the pressure to reduce the Laboratory's overhead rate to remain competitive, but it will exacerbate the shortfall from that required.

The impact of inadequate funding is continued noncompliance with regulations and DOE orders. The Laboratory risks substantial penalties for failure to comply, especially with the advent of rulemaking, which will give several DOE orders the force of law. Direct funding for ES&H compliance has been requested from DOE for the past 3 years through ES&H field work proposals. These proposals would allow ES&H programs to be brought up to compliance levels, after which normal overhead would suffice for maintenance of the programs. So far, no funding has been received for these proposals, and none is expected in FY 1993.

7 • Technology Transfer and Science and Math Education

7 • Technology Transfer and Science and Math Education

Technology Transfer Plan

During the past 5 years, Oak Ridge has demonstrated its leadership in technology transfer by implementing a series of aggressive measures to expedite the flow of technologies from the laboratory to the factory floor. The Energy Systems Office of Technology Transfer (OTT) has concentrated its attention primarily on executing license agreements, which now total 59. From these licenses, we have collected more than $1.6 million in royalties from more than $35 million in commercial product sales. Through our royalty-sharing program, we have distributed more than $250,000 to our employees. We have also seen the number of industry guest researchers spending at least 2 weeks at ORNL rise from 344 in 1985 to more than 1000 in 1991. The technology transfer program has also had a significant impact on the regional economy. Capital investment in Oak Ridge has risen from less than $8 million in 1985 to more than $45 million in 1991, highlighted by the opening of manufacturing facilities of two technology clients: Hertel Cutting Technologies, Inc., and Coors Technical Ceramics Company (Fig. 7.1).

The future looks even more promising. In FY 1991 we added a new tool that will greatly increase the commercialization of new inventions made at the DOE laboratories: innovative cost-sharing arrangements called cooperative research and development agreements (CRADAs). These agreements allow ORNL to enter into contracts with industry to share personnel, facilities, services, equipment, or other resources for the conduct of specified, mutually agreed-upon research or development activities.

Our plan calls for increases in every aspect of the technology transfer program. We anticipate fivefold increases in licensed product sales, royalty income, and funding for industry partnership agreement and CRADAs. In addition, we are targeting a threefold increase in active licensing agreements.

Technology Transfer and Global Economic Competitiveness

Our competitive preeminence in world commerce has eroded over the past decade. We are being challenged by our European and Japanese trading partners and by emerging nations of industrial significance in Asia and Latin America. In 1991the United States had

Figure 7.1
During his visit to ORNL on February 19, 1992, President George Bush attended the signing ceremony for a CRADA between ORNL and Coors Ceramics Company. Also present were Secretary of Energy James Watkins (standing left) and Secretary of Education Lamar Alexander (standing right). ORNL Director Alvin Trivelpiece (seated right) and Joseph Coors, chairman and CEO of Coors Ceramics, signed the 3-year agreement, which involves the development of manufacturing techniques for advanced ceramics.

a trade deficit of more than $150 billion. To maintain our standard of living, advance our foreign policy aims, and ensure our national security, we must reverse this trend and regain our competitive edge in the global economy.

Fueled by R&D, technological innovation is vital to our future because it is the key to advances in productivity. During the past 50 years, technology has been the most important generator of productivity growth, far surpassing the contributions of capital, labor, or economies of scale. The United States must advance and apply technology toward the goals of enhancing our economic vitality, maintaining our national strength, and improving our general well-being. We must apply new technology to improve our industrial productivity and competitiveness. Successfully directed to this purpose, new technology can provide us with our greatest comparative advantage and can ensure our industrial leadership in an increasingly competitive world.

An analysis by the President's Commission on Industrial Competitiveness pointed out that our nation's investment in total R&D (as a percentage of the gross national product) is on a level commensurate with other nations. They also pointed out, however, that the portion funded by the federal government is about 50% and, of this amount, more than 50% is directed toward defense-related purposes. Such countries as West Germany and Japan, on the other hand, devote the vast majority of their government-supported R&D toward civilian purposes. To restore global market competitiveness and to reverse the international trade imbalance, our nation must increase its efforts to develop technologies of commercial value.

The extent to which we approach effective R&D parity with our trading partners depends heavily on our ability to derive commercial benefits from federally funded R&D programs. More than one-third of the R&D supported by the government is conducted in the more than 700 federal laboratories, which employ about one-sixth of our nation's scientists and engineers. To optimize application of U.S. R&D results, we must make government-developed technologies readily available to the commercial sector, create a favorable environment for private-sector firms to invest in the commercial development of these technologies, and make it easier for U.S. industries to gain access to DOE scientific and technical talent and research facilities.

Industrial Partnership Programs

CRADA Emphasis Areas

In FY 1991, we began to promote CRADAs, which will greatly increase the commercialization of new inventions made at the DOE laboratories through innovative cost-sharing arrangements. These agreements allow ORNL to enter into contracts with industry to share personnel, facilities, services, equipment, or other resources for the conduct of specified, mutually agreed-upon research or development activities.

The gap between R&D and commercialization is one of the most difficult to bridge. It is very difficult to do in the same organization, and even more difficult to do across organizations. CRADAs provide a means to bridge that gap by providing industry with the opportunity to fully and expeditiously access the broad R&D capabilities at the DOE R&D facilities.

Energy Systems has already executed 23 agreements with a total value of almost $15 million, more than one-half of which comes from the contributions of our industrial partners. This experience, as well as that of the High Temperature Superconductivity Pilot Center Program, demonstrates that we have developed a process of teamwork and cooperation with DOE that strikes the proper balance of flexibility and consistency. We applaud the initiative of DOE-OR for providing the leadership in creating an environment in which the technologies developed can be transferred more effectively to the commercial sector.

We believe that a key to our mutual success has been the development of an understanding between both parties for the identification and protection of certain minimum government rights while retaining the required independence of the contractor to negotiate in a businesslike manner. This understanding involves the recognition on the part of Energy Systems of the importance of retaining certain contractual conditions but encourages discussion with DOE-OR personnel to resolve problems and to accommodate specific language that an Energy Systems client may desire to be included in the negotiation.

The following illustrations highlight just a few of the exciting opportunities we have to help U.S. industry become more competitive.

Environmentally Conscious Manufacturing • One of the unanticipated benefits of CRADAs has been the willingness of groups of companies or consortia to join with the national laboratories to attack larger-order problems of pressing national interest. Energy Systems and the National Center for Manufacturing Sciences (NCMS) are entering into a CRADA dealing with environmentally conscious manufacturing technology. NCMS is a consortium of over 125 manufacturing firms.

It is an indisputable fact that environmental concerns are more pressing issues today than at any other time in human history. This public emphasis on environmental protection concerns and the complexity of manufacturing waste issues makes it very difficult, sometimes impossible, for an individual company to comply with all the demands in a timely manner.

This program with NCMS will result in the commercialization of selected technologies developed primarily within the Y-12 Plant in waste minimization and site remediation. The data and technology developed in the CRADA will provide the means to reduce or eliminate hazardous by-products of manufacturing operations and to provide those technologies needed for site remediation.

Ceramic Manufacturability Center • Oak Ridge is a recognized leader in the development of advanced materials. Ceramics compose one class of these materials that holds a great deal of promise in a variety of industrial applications. Because they are lighter, stronger, more resistant to wear and capable of operating at higher temperatures than conventional materials, ceramics allow engineers to design machines that operate more productively, more efficiently, and with less probability of failure. In spite of impressive advances in performance, the large-scale application of these materials has been very slow because of their high cost relative to metal components. Continuation of this trend threatens the existence of the U.S. structural ceramics industry. A major cost component is the expense of finishing these ceramics to final dimension because they are difficult to machine. This cost often represents from 30 to 70% of the production cost. Therefore, identification of methods for greatly reducing machining costs for structural ceramic components could open large markets for U.S. manufacturers.

Oak Ridge stands alone in the federal system in that it includes both a major, multiprogram national laboratory and the Y-12 production facility housing a state-of-the-art computer-integrated manufacturing complex. In the area of advanced materials, this unique combination of facilities allows technology development that spans the R&D continuum through to deployment in an actual manufacturing environment. Capitalizing on this particular area of excellence, a Ceramic Manufacturability Center (CMC) is being established in the HTML. This will enable the staff and participants in this center to work closely with the six HTML user centers whose instruments and staff are organized to characterize materials from the scale of atoms to that of several centimeters. Within this CMC, Y-12 staff working with ORNL staff, will develop advanced manufacturing methods (with a first emphasis on machining technology) that can significantly lower the costs of structural ceramic components. The initial step will be to conduct collaborative research projects in this center with structural ceramic manufacturers, grinding media manufacturers, and machine tool builders. As the technology matures, it will be implemented in a production environment in the Y-12 Plant Manufacturing Technology Deployment Center that is expected to be operational in FY 1994. Six multiple-partner CRADA projects are expected to be in place within the first 12 months of the program. This CMC initiative will permit the United States to regain international parity in the multibillion dollar ceramics market.

High-Performance Computing • Energy Systems, together with DOE and several of its laboratories, has been working with the Computer Systems Policy Project (CSPP) to provide a better focus for the federal R&D investment on important, precompetitive, generic technologies for the computer industry. CSPP is an affiliation of chief exective officers from the 13 leading U.S. computer companies such as IBM, Apple, and Digital. We have negotiated a specially tailored model CRADA that we hope will significantly reduce the time taken to implement such an at any one of the labs. Shortening the approval-cycle time was considered critically important.

The CSPP recently reported that the United States still leads in half the technologies, mostly software-related, critical to U.S. dominance in the field. However, the report also said that the United States lags in the other half (mostly capital-intensive technologies) and that without positive action, the U.S. position in all sixteen critical technologies cited in the report will erode.

We have worked closely with CSPP to identify areas of unique capabilities at the various DOE facilities that could serve as the basis for cooperative development efforts:

- distributed operating systems and tools,
- parallel-processing algorithms,
- gigabit networking,
- parallel-programming tools, and
- simulation techniques.

Based on this review, CSPP envisions conducting multiple projects in these and other areas with each of the participating laboratories.

Advanced Automotive Initiative • Recent announcements of significant downsizing on the part of the three largest U.S.-based manufacturers (the so-called "Big Three" of Ford, Chrysler, and General Motors) together with President Bush's trip to Japan to discuss trade imbalances, emphasize the significant influence that the U.S. automotive industry has on our economy. Key competitiveness issues of the U.S. automakers depend on technological breakthroughs that will propel them beyond their foreign competitors to yield a new state of the art. Ford, for example, has recently announced plans for a "hybrid vehicle," one combining features of conventional internal combustion or turbine engines with electric drive components, as that kind of technological leap. We are aware that Chrysler and General Motors have ideas similar to Ford's.

General Motors, for one, has been aggressively pursuing collaboration with the federal laboratories as the means to leverage their own endeavors and to strengthen their technology development effort. The DOE laboratories in particular, because of the nature of their mission, are particularly well suited to work with the automakers. General Motors has already identified important technological resources at Oak Ridge, Sandia, Argonne, Idaho, and Los Alamos, for a start.

DOE, the national laboratories, and the Big Three automakers are working to identify development initiatives of mutual interest. These projects would be aimed at major leaps forward in technology, ensuring the preeminence of the U.S. automotive industry well into the twenty-first century. At this time we are close to consummating several CRADAs with the automakers.

Given the shared interest of the automakers, a natural starting point would seem to be in the area of electric or hybrid vehicles. The following potential projects involving DOE facilities could be based on their unique technology and capabilities:

- electric drive motors and associated power electronics;
- advanced sensors and sensor arrays;
- microprocessor technologies for imbedded, intelligent computer capability;
- advanced materials such as lightweight composites;
- advanced forming and fabrication processes, including composite tooling; and
- supercomputers for design and simulation studies.

This area has the additional advantages for our nation of reducing our dependence on fossil fuels and of improving the quality of our environment by reducing air and noise pollution.

"Spin-Off" Technologies

DOE-ER has created a new activity to support the performance of cost-shared CRADA projects with private industry to enhance the commercial applications of "spin-off" technologies arising from R&D programs performed at DOE-ER laboratories.

The following selection criteria apply:

- The technology must originate at a DOE-ER laboratory, with preference for technologies originally developed using DOE-ER funds.
- The technology should be a spin-off or "orphan" technology (one that does not fit the funding plans of another programmatic area).
- The laboratory's portion of CRADA effort should emphasize research more than product development.
- The technology should have significant commercial potential (e.g., it should be included on the U.S. Department of Commerce critical technology list or have significant commercial markets such as semiconductor technology).
- There should be evidence of substantial corporate commitment and enthusiasm for the project.
- The technology development effort should fit into the ongoing mission at the laboratory.
- There is a preference for working with small businesses.

ORNL has received authorization for four such projects in FY 1992 with a total budget of $1 million. We anticipate that up to 10 projects will be funded in FY 1993 with a total budget of $2 million. Based on DOE-ER projections, this program could grow to $5 million by FY 1997.

Licensing Oak Ridge Technologies

Intellectual Property Management

Although originally requested in 1984, a class waiver of patents and copyrights was not granted until mid-1991. With the class waiver, Energy Systems has obtained new responsibilities and authorities for managing its intellectual property portfolio. It is our policy to encourage and support those activities undertaken by our employees to facilitate this process through a dedicated program to promote the transfer and adoption of our technology in the commercial marketplace.

Because technologies often require additional development on the part of the private firm to produce a commercial product, companies are concerned about the nature and extent of the protection of proprietary property when adopting developments of federal R&D. During the past 4 years, we have filed an average of 25 U.S. patent applications each year. It is our goal to increase that number to an average of 75 each year over the next 5 years.

OTT has developed and implemented a technology transfer assessment process to (1) identify and screen reported items of technology to determine commercial market potential, (2) assess those items of technology as to technical merit and commercial market value and designate technology transfer candidates, and (3) develop strategies to bring designated transfer candidates to a state of readiness so that commercial client firms can evaluate the technologies for licensing and/or entering into a CRADA.

In light of the new authorities granted by the class waiver and CRADAs, we have undertaken an effort to update and modify our policies and procedures for technology assessment, licensing, and royalty sharing to address issues pertaining to conflict of interest, fairness of opportunity, equitable distribution of royalty income, and employee recognition and awards. In particular, we are incorporating into our internal policies and procedures the *DOE Interim Considerations/Guidelines* developed by the Technology Transfer Field Task Force.

Beginning in FY 1992 and thereafter, we will be working with ORNL management to promote increased levels of participation in the decision-making process as to which inventions are to be patented and what the orders of priority are to be. The goals of these efforts are to improve the timeliness and responsiveness of the patent application process and to enhance the role of intellectual property in R&D program planning and management. The ability to manage a Laboratory's patent portfolio should have the effect of emphasizing technical merit and commercial value in patentability decisions rather than using strictly "defensive" criteria (i.e., patenting things so that they cannot be sold back to the government for profit).

Licensing Program

From the beginning, OTT has concentrated its efforts on those areas of technology development for which Oak Ridge has become known for excellence. During the last 4 years we have averaged over 10 new license agreements each year. Over the next 5 years, we intend to increase this number to an average of 15 new agreements each year.

The most notable area of success is in advanced materials. From superalloys to ceramics to electronic materials, Oak Ridge is internationally recognized as a leader in developing advanced materials. In 1990 we produced a videotape of our capabilities and distributed more than 500 copies to advanced-materials firms throughout the United States. Other areas of commercially valuable technology include analytical instruments, waste management, intelligent systems, chemical processing, and biomedical technologies. Similar campaigns will be mounted in these other areas in the following years.

These licensed technologies are beginning to show up in the forms of new companies and commercial products. For example, ORNL developed a technology for automated separations of a single blood sample as part of NASA's Skylab Program in the 1970s. This technology was incorporated into a product that completes multiple analyses within minutes. The product allows these tests to be conducted right in a doctor's office rather than being shipped to a laboratory. Our client, Abaxis, Inc., was formed in 1989 at the time our license was executed. On Thursday, January 23, 1992, Abaxis completed their initial public stock offering. The offering was so successful that they expanded the original plan of stock sales from 1.75 million shares to 2.175 million shares, making it one of the most actively traded stocks for that day. In addition, the share price rose $4.75 from the offering price of $11 to close at $15.75.

To better respond to our industrial clients, we have organized our licensing executives so that they can specialize in one of these technology areas. This will allow each executive to maintain an in-depth awareness of ORNL capabilities and to gain added insights into industrial needs to promote more effective partnerships in the future. Each executive will be responsible for negotiating both licensing agreements and CRADAs.

There is synergy between our licensing programs and CRADA efforts, with licensing opportunities leading to CRADAs and vice versa. The availability of CRADAs is expected to have a tremendous effect on our licensing efforts. When a company comes to ORNL to discuss a CRADA in a particular area, these initial interactions often lead to expressions of interest in licensing other, complementary technology.

Use of Royalty Funds

Use of royalty funds received from licenses shall be governed by the provisions of Article 69 of the prime contract with the DOE. Authorized uses of the funds include the following:

- payment of federal income taxes, including interest and penalties;
- reimbursement of reasonable cost relating to the DOE's filing, prosecution, and maintenance of any waived invention;
- rewards to employees with royalty revenues consistent with the provision of Energy Systems Policy and Procedures TA-4;
- fund-maturation initiatives to meet technology transfer needs of licensees and potential licensees, including (but not limited to) production of sample materials for evaluation, preparation of additional documentation to facilitate adoption of a given technology, applied engineering to accomplish packaging or predictability, and product testing;
- activities that increase the licensing potential of other electable or waived subject inventions;
- payments to licensors or other contracting parties necessary to assemble a technology package or to facilitate licensing out, which agreements shall not include any guarantee or requirement that would obligate the government to pay any costs or create any liability on behalf of the government;
- contribution not to exceed 20% of the gross royalty revenues per year to nonprofit organizations to enhance technology transfer;
- activities intended to increase the capability or quality of the technology transfer program; and
- pledge income to finance advance payments required for projects related to technology transfer.

Technology Maturation

Many technologies invented at ORNL are not developed to a stage where private companies can accurately assess their commercial potential. In the past, funding was typically not available to develop a technology beyond a working model. Although capable of demonstrating technical feasibility, such models are often inadequate for a company to assess market applications, production costs, and the like for the technology. In many cases, alternative support is needed to construct advanced prototypes that are close to commercial production models. These models can be more easily used to assess the marketability of the technology.

Since 1984, we have provided at least $200,000 to be used to support projects focused on maturing a technology to the point where a more informed analysis of the technology's commercial viability can be performed. Over the last 4 years, this program has been funded exclusively out of royalty funds. This expense has accounted for the expenditure of about 50% of royalty income. It is our intention to continue this program at about the same level for the next 5 years.

The following factors are used to determine the authorization of maturation funds:

- Developmental status: the development should be ready for commercialization now. The proposer should not be seeking funds for additional R&D to improve or finish the development. The requested funds should be used to bridge the gap to commercialization.
- Impact factor: proposed funds should impact heavily whether or not the development is successfully transferred. If the inventor does not pursue the proposed activities, transfer of his development to the private sector will likely fail.

- Marketing factors: there should exist a real-world need and market for the development. The market should be large and, preferably, growing.
- Manufacturing factors: commercial use of the development should not require substantial manufacturing R&D. The requisite manufacturing capabilities should exist now or be easily attainable.
- Intellectual property factor: the effort should result in an improvement in the intellectual-property position of the technology. This can occur either through a new patent application or a new, improved understanding of the technology.

All projects will be documented by a final report that summarizes the impact of the project on the transfer of the technology.

Information Outreach

In 1991, OTT began the process of reexamining (1) goals, objectives, and the current approach to information dissemination; (2) the impact of our technology applications bulletins (TABs); and (3) alternative approaches. We commissioned a study of our TABs to determine who was receiving them and what the recipients were doing with them once they got them. The most interesting result was that our bulletins were being used primarily to keep track of parallel developments in a field, not as a means of identifying technologies for acquisition. In addition, an inordinate amount of our mailing list was for state and local governments. This is a group we feel should be reached by our program-specific publications, which are more focused on their issues of interest.

These results have led us to the following alternatives, which we began to implement in FY 1992:

- Audience
  - Review current mailing list to cull out entries unlikely to be oriented toward technology acquisition.
  - Begin to collect information on inquiries (by means of a trade press "bingo card") that we can catalog, and sort areas of interest for future, related mailings.
  - Mail selected bulletins to targeted firms having similar interests.
- Bulletins
  - Continue to refine and improve the market-application orientation that we have recently adopted for bulletins.
  - Produce unbound, individual bulletins that can be stored on a personal computer and printed on demand.
  - Produce a catalog of bulletins with brief (two- to three-sentence) abstracts of the bulletins.
  - An additional approach being pioneered by the National Institutes of Health is an electronic bulletin board that can be accessed by interested firms.
- Cover
  - Obtain an OTT logo that can be used to distinguish our future mailings.
  - Produce a permanent binder with the OTT logo on it to hold future bulletins and send it to firms on our mailing list.
  - Send out targeted mailings in an expandable folder with the OTT logo on it and containing bulletins and a business card.
- Advertising
  - An alternate approach to mass mailings may be the selected use of advertising in trade magazines (possibly in the mold of the Hughes yellow Tech Briefs pages).
- Bulletin preparation
  - In the future the responsible OTT licensing executive will have the responsibility of identifying technologies for which TABs should be prepared. We will try to

prepare a list each month, based on our Wednesday meetings and on Technology Evaluation Committee meetings, and turn it over to the TAB editor along with any relevant market information we have. These meetings will be used to decide on developing illustrations for preparation of technology view graphs.

Business Management and Budget

The budget for OTT in FY 1991 was $2.2 million; the number of FTEs supported was 21.6 (Table 7.1).

Table 7.1
***Estimated staffing and expenditures for the Office of Technology Transfer*[a]**

	FISCAL YEAR							
	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
	Funding ($ in millions—BA)							
ORTA[b] activity	1.63	2.19	2.23	2.37	2.47	2.58	2.70	2.82
Patent/licensing—activity	0.58	0.68	0.71	0.74	0.77	0.81	0.84	0.88
CRADA[c] funding—federal	3.90	12.40	20.60	21.63	22.71	23.85	25.04	26.29
CRADA funding—private industry	3.65	12.10	20.15	21.16	22.22	23.33	24.49	25.71
Total	**9.76**	**27.37**	**43.69**	**45.90**	**48.17**	**50.57**	**53.07**	**255.70**
	Professional Staffing [full-time equivalents (FTEs)]							
ORTA activity	11.60	15.25	17.08	17.08	17.93	19.77	20.76	21.79
Patent/licensing	5.00	6.25	6.88	6.88	7.59	7.96	8.36	8.78
CRADA activity	3.00	3.00	3.00	3.00	3.31	3.47	3.65	3.83

[a]Funding for the Energy Systems Office of Technology Transfer includes ORNL, the Oak Ridge Y-12 Plant, and the Oak Ridge K-25 Site.
[b]Office of Research and Technology Applications.
[c]Cooperative research and development agreement.

Productivity Indicators

Royalty income and the number of new licenses are constantly monitored and reported (Tables 7.2 and 7.3). These are important measures of tactical success. However, the measure for the strategic success, with respect to the OTT mission, is the dollar value of product sales resulting from our licensing agreements (Table 7.4). Product sales ending FY 1991 exceeded a cumulative total of $45 million.

Table 7.2

Office of Technology Transfer licenses executed (FY 1991)

Licensee	Technology
Ametek	Iron aluminide powders
Harrison Alloys	Iron aluminides
Harrison Alloys	Nickel aluminides
Microscience	Atom probe control software
Gamma-Metrics	Surface-enhanced Raman spectroscopy probe
Hoskins Manufacturing	Iron aluminides
Abkowitz & Associates	Integrated graphics railway data base
Fiveash Data Management	Raman spectral data
Texas Engineering Exp. Station	Raman spectral data
Sigma Science	Respfit software
Dosimeter Corp. of America	Alpha scintillation detector
Valvision	Check-valve monitoring

Table 7.3

Licensing income and use[a]

	FISCAL YEAR				
	1991[a]	1992[b]	1993[b]	1994[b]	1995[b]
Licenses					
Number of new licenses	12	25	25	25	25
License income ($ in thousands)	459	600	700	1000	1300
Use of income ($ in thousands)					
Employee awards	115	150	175	250	325
ORTA[c] office support	30	39	46	66	86
ntellectual property management	28	0	0	0	0
Cooperative research support	64	84	98	140	182
Other Lab R&D support	152	236	275	392	509
Retained by contractor	0	0	0	0	0
Other:					
Federal income taxes	20	26	30	43	56
Education/Training	0	0	0	0	0
Tennessee R&D	50	65	76	109	142

[a]Funds are for the ORNL Office of Technology Transfer, Martin Marietta Energy Systems, Inc., which includes ORNL, the Y-12 Plant and the K-25 Site.
[b]Projected.
[c]Office of Research and Technology Applications.

Table 7.4
Technology transfer results

	FISCAL YEAR				
	1991	1992[a]	1993[a]	1994[a]	1995[a]
Patent application	19	56	39	40	41
Patents granted	17	54	37	38	39
Cumulative product sales[b]	46.0	57.7	75.0	101.3	136.8

[a]Projected.
[b]Dollars in millions.

Science/Math Education Support Programs

Overview of ORNL's University and Educational Programs

The DOE Science Education Enhancement Act (Public Law 101-950), passed by the 101st Congress in November 1990, formally recognized the increased and growing importance to the accomplishment of the Department's mission of programs "to enhance the quality of mathematics, science, and engineering education." In establishing a new departmental policy in this area (SEN-23-90), Secretary of Energy James D. Watkins committed DOE "to take full advantage of the unique resources and facilities of the Department's national laboratories and research facilities for assistance in science and mathematics education improvement."

Secretary Watkins pledged the use of DOE's "significant resources" of highly trained technical staff and state-of-the-art facilities to help strengthen science and mathematics education nationally. Through SEN-23-90, he urged special attention to the following goals:

- the nation's youth from kindergarten through high school must be given a strong technical foundation on which to base future success in higher education and in science and mathematics careers;
- the nation's science and mathematics teachers must have in-depth and state-of-the-art training so they can present science and mathematics concepts in ways that spark student interest and understanding; and
- special effort must be directed at encouraging and supporting more women, minority, disabled, and disadvantaged students in mathematics and science at the precollege through university levels.

Commitment to these goals is reflected in a companion mandate to each of DOE's multiprogram national laboratories and other major facilities to make education at all levels, from precollege through graduate and professional, one of their primary missions. For this purpose, DOE has given ORNL and its sister laboratories the designation of regional "science education centers." This expanded mission places strong emphasis on helping to strengthen mathematics and science education in the schools. Special attention is given to design, development, and delivery of comprehensive and integrated programs for elementary and secondary teachers and students. These programs address the highest-priority national needs and objectives. Chief among these objectives are the six national education goals established by the president and the nation's governors, particularly Goal 4: "By the year 2000, U.S. students will be first in the world in science and mathematics achievement."

Secretary Watkins, as the first chairman of the Committee on Education and Human Resources of the FCCSET, has worked to implement a coordinated federal budget strategy, consistent with the national education goals, to improve science and mathematics education. Its priorities, centering first on the precollege area and on teacher preparation and enhancement, support four strategic objectives:(1) improved science and mathematics performance; (2) a strong precollege teacher work force; (3) an adequate pipeline for the science and technology work force, including increased participation of underrepresented groups; and(4) improved public science literacy.

Educational initiatives through ORNL's Science Education Center strongly support these goals and guidelines. New partnerships are strengthening the center's focus on the national education goals and on education reform within the southeast region. These partnerships include cooperative efforts with other agencies, including the Appalachian Regional Commission; state and regional schools, colleges, and universities; and the private sector. Support for these partnerships includes a major new focus on computing and communications technology for educational applications. The overall effort encompasses work with teachers and students from the early elementary grades all the way through the Laboratory's more traditional and long-standing involvement as a resource for undergraduate, graduate, and postgraduate study and faculty research participation. The primary objective is to help ensure an adequate work force for the accomplishment of the nation's future energy R&D goals.

Since October 1989, when DOE convened its Math/Science Action Conference in Berkeley, California, just one month after President Bush assembled the nation's governors in Charlottesville, Virginia, for an "Education Summit," ORNL's educational programs have expanded significantly in scope and impact. Among the major thrusts are the following:

- joint projects with UT to create an Academy for Teachers of Science and Mathematics that serves Tennessee and four other Southeastern states as well as an innovative program of alternative preparation and certification for technical professionals who wish to pursue second careers as science and mathematics teachers;
- the DOE-sponsored Project SMART (Science/Math Action for Revitalized Teaching), a partnership that joins rural and urban school systems in East Tennessee with ORNL and ORAU;
- the education component of DOE's High Performance Computing Center initiative, for which ORNL has been selected as one of two sites;
- expanded opportunities for women, minorities, and people with disabilities, including the establishment of customized internships in both technical and technical support areas;
- full-summer appointments as research associates for secondary teachers, including some 55 in residence last year at ORNL; and
- the ORNL-administered National Teacher Enhancement Project, sponsored by the NSF, which has provided summer workshops and academic-year follow-up training for more than 700 teachers of kindergarten through eighth grade nationally.

New programs also have included the following:

- sponsorship of summer mathematics and science camps for middle-school-age youth (and especially young women) on an area-wide and Southeast regional basis;
- development of a Saturday Academy of Computing and Mathematics, which draws on volunteers from the ORNL technical staff as mentors for area secondary students;
- the new Oak Ridge Educational Network, which offers access to high-performance computing capability for student and teacher projects as well as for networking and communications applications;
- expanded Tennessee and Southeastern U.S. involvement in the DOE-sponsored National Science Bowl;
- Energy Systems–wide coordination of school outreach (or adopt-a-school) partnership activities, including one with the Tennessee School for the Deaf;
- an annual "Women in Science" conference for undergraduates as well as high school age participants;

- introduction of new classroom teaching and enrichment resources such as the DOE-sponsored public television series, "The New Explorers"; and
- inauguration of a multistate regional Summer Science Honors Academy sponsored by the Appalachian Regional Commission as a companion to the DOE High School Science Student Honors Program in Environmental Sciences, conducted since 1988 at ORNL.

The ORNL Science Education Center's Long Range Plan, developed initially and implemented in FY 1990, incorporates both near- and long-term actions in response to the urgent national need to improve (1) the overall quality of science and mathematics teaching, (2) the size and diversity of the educational pipeline in these fields, and (3) the consequent future availability of the requisite numbers of people trained in scientific and technical skills. The approach is a comprehensive and cooperative one that emphasizes institutional partnerships and resource sharing for mutual benefit.

Key thrusts of the plan are designed to accomplish the following:

- strengthen the educational pipeline at its roots, qualitatively and quantitatively, through innovative student learning experiences beginning at the early elementary level;
- help correct the historic underrepresentation of women, minorities, and people with disabilities in technical disciplines;
- broaden the impact of these educational initiatives through increased emphasis on science and mathematics teachers and students, with special attention to teacher recruitment, preparation, and professional development and enrichment;
- diversify the Laboratory's own work force to better match the changing demographics of the U.S. population; and
- expand efforts to increase the scientific and technological literacy of the public at large.

The ORNL Science Education Center, administered through the Office of Science Education and External Relations, provides a framework and an operating structure to address these goals. Precollege programs allow both students and teachers to experience directly, through "hands-on" learning opportunities, the exciting frontiers of science and the process of discovery. In the case of the students, it is important that such challenging and creative experiences occur as a part of their earliest encounters with science.

Undergraduate programs affect students at a time in their academic development that is important in influencing the choice of a career and decisions on advanced study in energy-related fields. Graduate-level advanced study and research participation opportunities, which make further use of the Laboratory's unique facilities and staff resources, help prepare emerging scientists and engineers for their roles in national energy-related missions by providing a close association with ongoing energy R&D in a national laboratory setting. Faculty participation in joint or collaborative research facilitates the two-way flow of technical information and helps to establish a strong professional connection between those teaching and research staff members in schools and colleges who are the primary producers of scientific and technical personnel and the outside professional communities in all sectors—academic, government, and industry—that will be the source of their future employment.

At the precollege level, ORNL began a formal program in the summer of 1985 with the first pilot research participation appointments for science teachers. From a modest base, this activity has grown rapidly. A full-time coordinator for precollege activities was appointed in the fall of 1987. Currently, these programs serve up to 400 elementary and secondary teachers each year, some 125 students selected for special on-site honors study activities on both a national and a regional basis, and another 24 thousand student-teacher participants in "hands-on" learning experiences offered year-round through ORNL's Ecological and Physical Sciences Study Center. This core precollege program presents some 40 different topical study units to visiting class-size groups and in outreach programs presented in schools within a 100-mile radius. Beginning in 1990, ORNL conducted its first residential 10-week research participation program for students at the secondary level. The joint effort initially involved seven outstanding high school juniors and seniors and two teachers from Puerto Rico and has continued each summer since then.

A continuing strong emphasis in this comprehensive approach to strengthening the mathematics and science educational pipeline has been ORNL's interactions with historically black colleges and universities (HBCUs) and other MEIs. The Laboratory is a partner with two other national laboratories (Los Alamos and Sandia) in the historic DOE Science and Technology Alliance, which in 1988 linked these facilities with three MEIs: the Ana G. Méndez University System in Puerto Rico, New Mexico Highlands University, and North Carolina A&T State University. The DOE-sponsored Waste Management Consortium of 17 minority colleges and universities represents another key link, as does ORNL's participation in the National Consortium for Graduate Degrees for Minorities in Engineering, Inc. (GEM). Currently, ORNL administers some 20 subcontracts, representing commitments of more than $4 million, with minority institutions. Six new customized internship programs have been developed under subcontracts with minority institutions that provide training assignments in ORNL divisions for both undergraduate and graduate students.

DOE's University Laboratory Cooperative Program (ULCP), administered through its Office of University and Science Education Programs in Energy Research (ER), supports research participation and training opportunities for students and faculty at ORNL through a joint effort with ORAU. Many more participants are supported directly by programmatic funds supplied by the Laboratory's research divisions and support through other sources, such as colleges and universities, fellowship awards, and contracts and grants.

ORNL plays an important role in the education and training of students at all levels through myriad programs designed to provide advanced study and research opportunities. School, college, and university guests are hosted by the Laboratory through a variety of mechanisms:

- awarding R&D subcontracts;
- encouraging short-term research in the designated DOE user facilities and other resources;
- supervising students and collaborating with faculty through research participation appointments;
- visits of technical personnel and equipment loans;
- establishing close collaborations with specific universities and university consortia, appointing teachers as research associates, and offering professional development workshops and student enrichment experiences; and
- providing learning experiences through the Ecological and Physical Sciences Study Center.

DOE and ORNL benefit directly from the mission support gained, especially from university-level participation programs. Projections performed for DOE indicate that the demand for well-qualified, trained scientists and engineers will continue to increase, particularly in fields such as health physics and computer science. At the same time, trends point to a decreasing number of science and engineering graduates, especially those who are U.S. citizens. To ensure a supply of personnel to perform energy-related research, DOE has a comprehensive program designed to improve the quality of science education and to increase the number of students electing to study science. ORNL plays an integral role in this program to enhance the research capabilities of educational institutions and to train students for careers in research.

College and university partnerships represent a mutually beneficial and highly cost-effective way to support ORNL's programmatic goals, while making vital educational and training contributions. During the more than two decades that ORNL has hosted undergraduate students on academic-year science semester programs, students have made substantive contributions to ORNL projects that later were patented and/or received R&D 100 awards. Furthermore, working with college and university personnel helps to fulfill the Laboratory's technology transfer objectives.

More than 35 individual programs—undergraduate, graduate, postgraduate, and faculty—enable students and faculty to participate in ORNL research. About half of these summer and/or academic-year appointments are administered jointly with the Science/Engineering Education Division of the Oak Ridge Institute for Science and Education (ORISE), which is managed and operated by ORAU.

During FY 1992, students and faculty from some 135 higher-education institutions spent significant time at ORNL, using state-of-the-art resources while they were under research participation appointments. DOE supports a variety of university programs at ORNL, both through ULCP and programmatic funds.

More than 100 co-op students were employed at ORNL and elsewhere in Energy Systems in FY 1992; another 400 undergraduate and graduate students, 80 postgraduates, and 70 faculty members received research participation appointments. These numbers do not include another 100 college and university faculty and students who made short-term research visits under travel contracts. The supported visits may be to perform experiments at user facilities and resources or may be used for consultations with ORNL staff about common research interests.

University Consortia

ORNL has active working relationships with several university consortia. For example, ORNL has had a long-standing collaboration with ORAU/ORISE on educational programs that has been strengthened through the implementation of several new joint programs and joint university outreach activities. More recently, these activities have included the SURA, established to build and manage DOE's new Continuous Electron Beam Accelerator Facility at Newport News, Virginia. In FY 1989, ORNL became a partner with ORAU and SURA in a new initiative to establish the Center for Advanced Study in Materials Science at ORNL. This collaboration will provide a mechanism for faculty and students from SURA schools to work as teams on research projects at ORNL. Dissertations will be presented on these projects for graduate students to earn either a master's or a Ph.D. degree. Papers will be issued through ORNL for the participants to receive their degrees. ORNL also continues to have a strong "science semester" program with the Great Lakes Colleges Association/Associated Colleges of the Midwest (GLCA/ACM), which is now in its third decade. The long-standing success of this program helped to strengthen the case for DOE's national Science and Engineering Research Semester (SERS) Program, which provides for about 70 appointments annually at ORNL for undergraduate students from institutions throughout the country.

R&D Subcontracts

ORNL awards some 100 R&D subcontracts, valued at nearly $20 million, to more than 36 universities annually. These subcontracts generally sponsor research on campus but may also include provisions for student internships or faculty appointments to perform research at the Laboratory. About one-third of ORNL's subcontract obligations are with UTK (including the cost for the joint appointments under the Distinguished Scientist Program and other activities carried out through the Science Alliance, a UTK/ORNL Center of Excellence supported by the state of Tennessee).

Research Collaborations

Many long-standing collaborations between ORNL and individual universities are based on mutual research interests. Most of these collaborations involve outstanding departments at these premier research institutions and include active exchanges of students and faculty.

ORNL is also engaged in a team R&D effort for the deployment of an advanced robotic system capable of performing tasks hazardous to humans and/or whose execution times can be reduced if performed by automated systems. The goal of this project is to develop a generation of advanced robotic systems capable of performing surveillance, maintenance, and repair tasks in nuclear facilities and other hazardous environments. This goal will be achieved through a collaboration among ORNL; the universities of Florida, Michigan, Tennessee, and Texas; and each institution's industrial partners. This program takes full advantage of existing resources at all of the participating institutions. Besides its own research, ORNL coordinates the overall effort, including integrated equipment tests to demonstrate the overall progress of the team.

Newest among these collaborations are cooperative agreements signed in FY 1991 with the National University of Mexico and a collaborating scientist agreement with UT. The latter agreement is expected to serve as the prototype for a widening range of interactions with academic institutions, both statewide and beyond.

ORNL's Center for Global Environmental Studies expands activities under the DOE-sponsored Carbon Dioxide Information Analysis and Research Program to include other trace gases important in the greenhouse effect, causes and effects of ozone depletion, and the role of deforestation and reforestation in the climate issue. The center draws heavily on contributions from universities, other DOE laboratories, and outside research institutions.

Through DOE's Excess Research Laboratory Equipment (ERLE) program, ORNL helps colleges and universities to obtain excess equipment for the cost of transportation only. The equipment ranges from small detectors to sophisticated analytical instruments and may be new, used, or in need of repair.

Besides providing equipment resources, ORNL works with academic institutions to enhance their educational programs and research capabilities by donating personnel and resources. ORNL staff members frequently give seminars at universities throughout the nation, either because of an ad hoc invitation from faculty or through formal programs such as the ORAU Traveling Lecture Program and the Industrial Research Institute (IRI) Visiting Scientists Program. These visits, typically lasting a day, allow students and faculty to consult extensively with the scientist and give university personnel insights into some of the cutting-edge science performed at the Laboratory. About 75 to 100 of these visits are made annually.

Many ORNL staff members are affiliated with universities on an adjunct basis to teach classes and to collaborate with faculty on research projects. Some 20 to 30 ORNL research staff members hold formal part-time adjunct appointments from UT. Many others donate their teaching talents to UTK and other area institutions, among them Knoxville College, Tennessee Technological University, Pellissippi State Technical Community College, and Roane State Community College at its Harriman and Oak Ridge campuses.

ORNL technical staff members teach short courses as part of the ORAU/ORISE manpower training programs sponsored by DOE. ORNL also provides other types of assistance to faculty, including critical review of proposals and manuscripts and organizing joint meetings and conferences.

Facilities and Equipment at ORNL

ORNL currently operates 11 designated DOE user facilities, which offer unique opportunities for outside researchers from both industry and universities to perform experiments on state-of-the-art equipment at minimal cost. Many of these facilities are supported by separate operational funds, and users need pay only their travel and housing costs.

In FY 1992, 427 university researchers performed experiments for 12,533 user days at these ORNL facilities. The largest percentage of the university-based users (22%) perform research at the Holifield Heavy Ion Research Facility. Other facilities heavily used by university researchers include the HTML, the 12,000-acre (5,500-hectare) Oak Ridge National Environmental Research Park and the Surface Modification and Characterization/Collaborative Research Center.

Unique resources available to university researchers include supercomputing capabilities, advanced electron microscopes, analytical equipment (including a Fourier transform mass spectrometer), and X-ray and neutron-scattering facilities. The Walker Branch Watershed, located on the Oak Ridge Reservation, is one of the best sites in the world for watershed research.

Precollege Programs

ORNL has been responsible for a host of new precollege student and teacher programs in response to both local and national mathematics and science education initiatives. The quantity and quality of science and mathematics training at both the college and precollege levels is declining. Some of the problems have been manifested in the universities in terms of poor precollege preparation and declining enrollment, especially of U.S. citizens and minorities.

ORNL-sponsored teacher training and workshop activities involve more than 400 teachers each year. Educational technology is being developed as a major theme of the Laboratory's precollege outreach activities with both students and teachers. One example is the new Oak Ridge Educational Network (OREN), which provides access to state-of-the-art computing facilities, including DOE's National Education Supercomputer, for networking and communications as well as mathematics and science problem solving and a variety of federally supported information services. Also new at ORNL in the summer of 1992 was the first "Adventures in Supercomputing" workshop conducted for 19 Tennessee teachers as part of the new federal High Performance Computing Center initiative, for which ORNL was selected as one of two primary locations. OREN provided the access for the teacher participants during the workshop and in their classroom applications of the course content. For the fifth year in 1992, outstanding students representing all 50 states, the District of Columbia, Puerto Rico, and seven foreign countries, were hosted by ORNL for 2 weeks under the DOE High School Science Student Honors Workshop Program. In this activity, which focused on environmental research, students worked in small groups under the guidance of ORNL research staff members on projects that examine the effects of contaminants on the environment. A parallel program, begun in in FY 1991, was the Appalachian Regional Commission–supported Summer Science Honors Academy for 35 student and 11 teacher participants who represented 10 of the 13 Appalachian Regional Commision member states. The Special Honors Study Program implemented at ORNL in FY 1986 allows exceptional high school students to receive one-on-one instruction from staff mentors. Six FY 1992 participants brought the total to 44 since the inception of this program.

New initiatives target traditionally underrepresented groups of students in an effort to increase the pool of those who pursue further study and careers in science and engineering. One example is Project SEED (Summer Educational Experience for the Disadvantaged), administered nationally by the American Chemical Society, to encourage minority and economically disadvantaged high school students to consider careers in science and mathematics. The FY 1992 program included 18 students who held 8-week summer appointments, 11 of them Hispanic students from Puerto Rico. Participants are involved not only in research but also in weekly career orientation activities and other seminars that expand their knowledge of the frontiers of science.

As part of this increased focus on precollege activities, ORNL continues to expand the Ecological and Physical Sciences Study Center (the Study Center), which is one of the most visible and successful precollege programs. The Study Center was formerly the Ecological Study Center of the Oak Ridge National Environmental Research Park. Developed by a team of educators, the Study Center began in 1983 with four study units, functioning during the spring and fall. The Study Center now includes more than 40 study modules that provide students with the opportunity for hands-on learning in both the life sciences and physical sciences. The units are offered generally as half-day field activities and are tailored for all academic levels from early elementary through junior and senior high school students. The Study Center now operates year-round, including Summer Science Experience camps for middle-school-level students and teacher workshops that transfer course content for local use. During FY 1992 more than 24 thousand students and teachers participated in Study Center activities, with a continuing special emphasis on students with physical and/or sensory disabilities.

ORNL's first school partnership activity, called PALS (for Partners at the Laboratory in Science), began with the Oak Ridge Schools in 1988. Since then the Laboratory has formally "adopted" Eastport Elementary and Vine Middle schools, which serve predominantly minority populations in Knoxville; Roane County High School in a neighboring, largely rural area; and the Tennessee School for the Deaf. The DOE-sponsored Project SMART (Science/Math Action for Revitalized Teaching) extends this program to three other East Tennessee systems (Chattanooga City, Harriman City, and Roane County) and a total of 55 schools. These partnerships make the Laboratory's unique skills and knowledge base as well as surplus equipment available on loan to assist the schools in enhancing the educational experience and opportunities for professional development available to both students and teachers. The Office of Science Education and External Relations now also coordinates school partnerships involving other parts of Energy Systems, significantly extending the region-wide outreach.

Undergraduate Programs

A prime emphasis in ORNL educational efforts lies with programs geared to college and university students who major in science, mathematics, computer science, or engineering. The primary goal is to encourage students to pursue graduate studies and careers in these disciplines. The third annual "Women in Science" conference, conducted jointly with ORAU, supports a growing outreach to increase the number of women and minorities who consider technical careers.

Participants in semester-length programs are increasing in number. Admission to the GLCA/ACM Fall Semester, a program of long standing at ORNL, continues to be sought after by students from the colleges of those consortia of midwestern liberal arts institutions. A 10-year survey indicated a pronounced effect of the Oak Ridge experience on pursuit of graduate studies and career choices in the technical fields. The SERS Program has completed its fifth annual cycle at ORNL and five other national laboratories. At ORNL, the experience has been modeled after the pioneering GLCA/ACM Program. SERS attracts students from colleges and universities across the United States,with about 70 participants each year at ORNL. The long-standing Student Research Participation Program offers 10-week summer appointments in ORNL research divisions for 30 or more undergraduates. Other programs providing extended term appointments for undergraduates include the Professional Internship Program in which appointees can do research at the Laboratory for up to 12 months consecutively and for a total maximum term of 18 months. The Technology Internship Program, developed to enhance training for technical students at 2-year colleges, is similarly structured to allow longer and more flexible terms of appointment and has become the source of several permanent technical employees at ORNL.

Summer educational programs make it possible for students to work in the ORNL research laboratories for about 10 weeks. These terms are generally open for most students and are a popular avenue for many who wish to experience research at a national laboratory. The Service Academies Research Associates (SARA) Program, another relatively new program, provides summer research opportunities for rising seniors from the U.S. military academies.

Graduate and Postgraduate Programs

Prethesis master's degree and Ph.D. candidates, other students performing thesis or dissertation research, and postdoctoral applicants are appointed to ORNL through various graduate and postgraduate education programs. The goal is to enhance the educational experiences of these students by providing opportunities to work in laboratory situations and with advanced equipment not readily available on their school campuses. A major consideration in the selection of these students is the compatibility of their background and interests with research projects in ORNL divisions. Postdoctoral and laboratory graduate participation (thesis research) participants must be accepted by ORNL's Graduate Fellow Selection Panel or through national panels established by OHER and Office of Fusion

Energy. During FY 1991 OHER introduced two new programs in parallel with the Alexander Hollaender Distinguished Postdoctoral Fellowships, now in their fifth year. These programs support work in the areas of human genome research and global environmental change. A total of 102 postdoctoral fellows and 12 doctoral candidates performing thesis research were in residence during FY 1992. In addition, ORNL makes several postdoctoral appointments annually through its own Eugene P. Wigner postdoctoral fellowships administered by the Human Resources Division and is a participant in the newly established DOE Distinguished Postdoctoral Research Program.

Early in 1992, ORNL announced a new and expanded Postdoctoral Research Program. This action further strengthens the Laboratory's long-standing commitment to excellence in research while contributing to the development of the new Ph.D. scientists and engineers on whom the future of the Nation's R&D enterprise depends. Goals are to

- advance scientific and technical training in areas of critical national need,
- provide research opportunities for outstanding scientists and engineers,
- promote the influx of new ideas and skills into the laboratory, and
- enhance interactions with the wider academic and research communities.

Postdoctoral appointees become integral members of ORNL R&D teams, gain exposure to current national issues in science and technology, have an opportunity to share and exchange innovative ideas and techniques, make significant contributions to ORNL programs, and enhance their own professional development.

Graduate degree candidates, performing research for theses or dissertations, work under the supervision of a graduate committee composed of representatives from their school and from ORNL.

Students who have not yet completed the required course work can participate in the Professional Internship Program for graduate students or the Graduate Student Research Participation Program. These programs are structured to provide prethesis research experiences for students aspiring to degree candidacy. Many of these participants are selected later for the higher level programs.

Faculty Programs

Faculty research appointments at ORNL are made through various programs for terms of a few days, 10 weeks to 3 months in the summer, or up to 6 months or a year for sabbaticals. These appointments include short-term visits, collaborative or student-faculty team projects, shared research equipment, participation at one of 11 officially designated ORNL user facilities, and programs that emphasize underrepresented minority participation such as those developed specifically for faculty members of HBCUs and other MEIs.

Goals for faculty research participation programs prioritize technology transfer, the university's own energy-related research interests, and enhancement of curriculum offerings. Faculty are selected for appropriate backgrounds and interests that will best contribute to the achievement of nationally important missions of DOE and other federal sponsors of ORNL R&D. ORNL faculty appointments also result in improved recruitment of students in the areas of science, mathematics, computer science, and engineering through faculty mentoring and ORNL staff contacts and interactions.

Minority Educational Institutions

ORNL has continued to expand the number and dollar value of its program interactions with HBCUs and with other MEIs. The main thrust continues to be on generating collaborative opportunities through internal and external interactions. Internally, the program emphasizes communication of Energy Systems' MEI program objectives; externally, attempts are made to encourage MEI participation in research through workshops, established contact networks, mutual visitations, and professional assistance. Program activities and initiatives are under way with a number of institutions toward the overall goal of increasing the number of scientists and engineers to help contribute to the manpower needs projected for the future.

Twenty-six subcontracts with a total value of more than $4.5 million are currently in place with minority institutions. Under these agreements, FY 1991 costs totaled more than $1 million. Six of these subcontracts support customized internship programs for student training, primarily in technical-support areas.

The memorandum of understanding (MOU) with the University of Puerto Rico (UPR) established in FY 1988, aims to increase interactions with Hispanic institutions. During FY 1992 the MOU provided a mechanism to support one faculty member for research at ORNL.

As part of the historic memorandum of understanding and intent that provides support through DOE's Office of Energy Research for the Science and Technology Alliance, ORNL continued collaborations with the three Alliance educational institutions: North Carolina A&T State University (NCA&TSU), New Mexico Highlands University, and the Ana G. Méndez University System in Puerto Rico. Under its primary relationship under the Alliance, ORNL for the fourth year provided funding to NCA&TSU in the amount of $372,200 to support program administration, student and faculty development, curriculum development, and special precollege programs to help encourage science and engineering students.

FY 1992 also included extensive interaction between ORNL and Alliance faculty and students from the Méndez University System in Puerto Rico. And, for the third year, ORNL provided support to New Mexico Highlands University in the establishment of a library to support their efforts to achieve and maintain Accrediting Board for Engineering Technology (ABET) accreditation for their School of Engineering Technology. ORNL supported precollege students and faculty through a special initiative that was developed last year. In addition to existing subcontracts in materials science with NCA&TSU, which have been ongoing for several years and funded to the sum of over $1.5 million, this period saw an expansion of these R&D collaborative efforts between ORNL and NCA&TSU into a new area: mathematical modeling (symbolic modeling of mechanical manipulators). A subcontract was let for $20 thousand to the school's Mechanical Engineering Department. The ORNL Information Services Division also supported a subcontract with the NCA&TSU Mass Communications Department. The purpose of the subcontract is for ORNL to develop an internship program with an MEI that will produce a cadre of trained professional technical information specialists for ORNL. The initial cost of the subcontract is $25 thousand. Eight students and one faculty member from NCA&TSU participated in summer internship experiences.

Eleven outstanding Puerto Rican high school students and two supervising teachers selected by the Méndez University System were brought to Oak Ridge for 8-week Summer 1992 research appointments. Each carried out his or her own independent research project and prepared a summary research report on the experience, which was reviewed and approved by the staff mentor. The students also took part in a weekly seminar with 11 other students appointed from schools in the East Tennessee area. At these sessions, students heard informal talks on various ORNL research programs, including fusion energy, genetic engineering, neutron activation analysis, and robotics, as well as sharing the progress of their individual projects. These very high-ability students and teachers selected by the Méndez Foundation for this experience proved to be not only highly capable and mature in approaching and carrying out their research assignments but also very positive and disciplined in adapting to their new laboratory work and living environments.

ORNL and Energy Systems have MOUs with three other MEIs including Southern University, Clark Atlanta University, and Tuskegee Institute. In addition to faculty and student appointments, subcontracts totaling more than $490,000 with these institutions support mission-related research.

The University of Tennessee, Knoxville

Because of its geographic proximity to UT's Knoxville campus, ORNL has long enjoyed a close and mutually beneficial relationship. Many UTK faculty members have served as consultants and research participants at ORNL. ORNL staff, in turn, have served as adjunct faculty and on UTK advisory committees. Many ORNL staff have taken advantage of the UTK Resident Graduate Program in Oak Ridge, which offers evening courses to those pursuing an advanced degree in a variety of scientific and engineering disciplines.

A significant new joint venture is co-publication of the quarterly journal, *Forum for Applied Research and Public Policy.* Two special FY 1992 issues contain articles by national academic and governmental leaders on education reform and achievement of national education goals. The history and current vigorous development of the overall UT-ORNL partnership was the subject of a 24-page special section in the quarterly *ORNL Review* (Vol. 24, No. 2, 1991).

Science Alliance With UTK

ORNL is a partner with UTK in the Science Alliance, the state of Tennessee's oldest and largest academic center of excellence. This activity, funded by the state of Tennessee, ORNL, and DOE under the state's Comprehensive Education Reform Act, is a prime example of university-laboratory collaboration in the planning and conduct of frontier research. The Science Alliance encourages joint projects between ORNL and UTK, thus fostering a unique environment for research training.

The most visible activity under this umbrella organization is the Distinguished Scientist Program, which has attracted 11 scientists and engineers of high national and international stature to tenured positions as full professors at UTK and to appointments as senior research scientists at the Laboratory. ORNL and UTK share these costs equally. Substantial impacts are evident in the number of personnel and contract awards that have accumulated since the start of these appointments. The new Collaborating Scientist Agreement, modeled after the Distinguished Scientist Program, is expected to further expand interactions at all levels between the two institutions.

The Science Alliance also sponsors a summer research program at ORNL for undergraduates and the development of a joint graduate program, including a Master of Science program in biotechnology and a graduate program in measurement and control engineering.

The UTK Graduate Programs at ORNL

Perhaps the least known but strongest ORNL-UTK joint programs are the two UTK graduate schools located at ORNL. The Oak Ridge Graduate School of Biomedical Sciences (ORGSBS) is more than 20 years old, and the Graduate Program in Ecology is in its second decade. Both programs at ORNL provide a home for several UTK faculty.

Housed in the Biology Division at ORNL, ORGSBS offers full-time graduate study for M.S. and Ph.D. degrees and for postdoctoral training. Student support is provided by UTK through research assistantships and federal grants. Most of the school's teaching and research training is provided by Biology Division staff. Current enrollment stands at 20 graduate students and postdoctoral appointees.

Similarly, the Graduate Program in Ecology, located within the Environmental Sciences Division, offers full-time graduate study for M.S., Ph.D., and postdoctoral students and is largely supported by ESD programmatic funds. About 20% of the research training is provided by ESD staff, who also teach courses under adjunct appointments. Enrollment totals about 15 graduate and postgraduate students.

Summary

The Office of Science Education and External Relations projects strong growth and development over the 5-year planning period as ORNL's Science Education Center continues to serve as a model for other federal laboratories and corporate entities in their efforts to enhance the mathematics and science skills of the nation's youth. ORNL has demonstrated a commitment to innovative precollege educational activities for both students and teachers and to increasing the involvement of university personnel in its R&D activities. These programs assist DOE in achieving its enlarged educational mandate both by providing opportunities for students of all ages to receive training and to perform research and by encouraging students to consider advanced studies in energy-related disciplines. College and university interactions contribute importantly to technical manpower development and to academic science and technology capabilities, both through sponsorship of student and faculty research participation and visits at ORNL and through reciprocal on-campus visits and lectures by ORNL staff. Collaborative research programs with college and university personnel continue to be a highly cost-effective method to help achieve DOE and national education goals while benefiting from the strong contributions that academic participants make toward fulfilling the Laboratory's important national R&D missions (Table 7.5).

Table 7.5

Participation in science and math education programs

	FY 1991			FY 1992		
	Total	**Under-represented minorities**	**Women**	**Total**	**Under-represented minorities**	**Women**
Precollege Student Programs						
Special Honors Study	8	0	4	6	0	1
DOE Honors Workshop	59	11	35	61	4	36
Ecological and Physical Sciences Study Center	19,700	1,470	10,200	24,333	2,876	12,300
Clinch River Environmental Studies Organization	30	2	17	18	1	12
Summer Science Experience	50	5	25	50	3	16
Project SMART/Math Quest	68	10	37	–	–	–
Wesleyan College Spectacles	34	9	34	63	12	63
Project SEED	18	5	6	7	2	5
Hispanic SEED (Science and Technology Alliance)	11	11	6	11	11	5
ARC Science Academy	32	0	19	35	3	15
SaturdayAcademy of Computing and Mathematics (SACAM)	74	7	32	96	3	43
Total	**20,084**	**1,530**	**10,415**	**24,680**	**2,915**	**12,496**
Precollege Teacher Programs						
NSF Workshop	45	2	38	45	7	42
DOE Honors Workshop	6	1	3	4	0	2
Appalachian Regional Commission	10	1	8	11	1	6
DOE Teacher Research Associates	55	5	26	54	5	26
DOE Lyndhurst Fellows	10	1	5	11	2	8
Project SMART Workshops	74	7	40	102	20	90
Hands-On Science Workshop	30	3	17	56	10	50
Adventures in Supercomputing	–	–	–	19	3	13
Tulsa Science Enrichment	–	–	–	20	2	15
Saturday Academy of Computing and Mathematics (SACAM)	18	0	12	22	1	15
Science and Technology Alliance	2	2	2	2	2	2
UT Teacher Academy	73	5	42	72	11	46
New Explorers Workshop	50	3	29	–	–	–
Puerto Rico Institute	–	–	–	22	22	17
Total	**373**	**30**	**222**	**440**	**86**	**332**

Table 7.5
(continued)

	FY 1991			FY 1992		
	Total	Under-represented minorities	Women	Total	Under-represented minorities	Women
Undergraduate Program						
GLCA/ACM	25	1	8	18	0	10
Research Semester (SERS)	60	8	20	69	11	27
Summer Technical Internship (HBCU)	49	49	23	86	10	31
Professional Internship Program	25	0	6	34	3	9
Technology Internship Program	25		6	19	0	6
HBCU Nuclear Energy Training	17	17	6	6	6	2
Service Academies Research Assoc.	4	0	0	1	0	0
DOE Scholarship Practicums	0	0	0	3	0	2
Cooperative Education	20	20	7	104	19	24
Science and Technology Alliance	2	2	0	1	1	0
Student Research Participation	31	0	10	37	5	9
Special Summer Program (SERS)	15	1	11	27	6	13
Customized Internships	10			7	7	4
University of Puerto Rico	2	2	2	3	3	2
Environmental Management (EMCOM)	–	–	–	4	4	1
Total	**285**	**101**	**100**	**419**	**75**	**140**
Graduate Programs						
Service Academy Research	2	0	0	0	0	0
Professional Internship Program	23	1	5	25	1	5
Laboratory Graduate Participation	12	0	4	11	0	3
Graduate Student Research	21	1	11	31	3	14
Nuclear Engineering Research	13	1	11	3	3	1
Law Internship Program	5	0	1	11	1	5
Graduate Education for Minorities	2	2	0	6	6	0
DOE Fellowship Practicums	8	0	4	4	0	1
Research Travel Visits	–	–	–	18	0	2
Materials Research (AIC)	–	–	–	1	1	0
Total	**86**	**5**	**36**	**110**	**15**	**31**
Postgraduate Programs						
ORNL Postgraduate Research	24	0	5	42	1	4
Hollaender Postdoctoral Program	6	0	0	5	0	0
Postgraduate Research Training Program (Lab co-op)	29	1	6	48	1	8
Fusion Energy Postdoctoral Program	3	0	0	4	0	0
Wigner Postdoctoral Fellows	2	0	0	2	1	1
Human Genome	–	–	–	0	0	0
Global Change	–	–	–	1	0	0
Total	**64**	**1**	**11**	**102**	**3**	**13**
Faculty Programs						
Faculty Research Participation	31	3	3	42	1	4
Minority Institution Travel	5	5	1	7	7	4

Table 7.5
(continued)

	FY 1991			FY 1992		
	Total	Under-represented minorities	Women	Total	Under-represented minorities	Women
Research Travel Visits	50	4	10	80	0	6
HBCU Faculty	11	11	3	13	13	2
University of Puerto Rico	1	1	1	1	1	1
Science and Technology Alliance	–	–	–	1	1	1
Great Lakes Colleges	3	0	1	2	0	0
Environmental Management (EMCOM)	–	–	–	3	3	0
Total	**101**	**24**	**19**	**150**	**26**	**17**

Guest Research and User Facility Programs

The Office of Guest and User Interactions (OGUI) is the focal point for cooperative interactions between ORNL and outside groups. OGUI functions include development and execution of agreements with all user facilities; implementation of guest research assignments; foreign national visit/assignment approvals for all Energy Systems facilities; provision of on- and off-site guest services; and coordination of ORNL cooperative research activities. OGUI is also responsible for oversight of DOE-ER projects funded through the Technology Transfer Program.

User Facilities

ORNL has 11 designated user facilities designed to serve both the technical community and DOE missions by making unique facilities and equipment available to outside organizations (Figs. 7.2 and 7.3). Because nonproprietary research can be conducted without cost to the user, these facilities constitute a resource that is increasingly attractive to scientists from both academia and the private sector (Fig. 7.4). In FY 1991, 534 university and industrial scientists, 479 government laboratory researchers, and 77 foreign guests conducted experiments at ORNL user facilities. This total of 1090 experimenters represents a 22% increase over the previous year (Table 7.6).

Traditionally, more than one-half of the ORNL user community represents universities. In 1991, 39% of the total were university scientists. Industrial scientists represent a growing segment of the user population with 107 experimenters representing 50 companies participating during the last fiscal year—a 27% increase over FY 1990 (Table 7.7).

The HTML, the focus for research on new ceramics and metallic alloys for high-temperature applications, expanded its program by adding two new user centers: (1) the Ceramic Specimen Preparation Laboratory that houses several instruments for machining and surface geometry characterization measurements and (2) the Residual Stress Laboratory, which features an integrated system consisting of an 18-kW rotating anode generator and a stress/texture goniometer. The system includes extensive, "user friendly," computer control and analysis software. The X-ray residual stress system is the first stress/texture system coupled to a high-flux rotating anode generator in the United States.

A proposal has been submitted to DOE for approval to designate the Productivity Validation Test Bed (Test Bed) within the Engineering Technology Division as a national user facility. The Test Bed is associated with the Survivable Optics Manufacturing

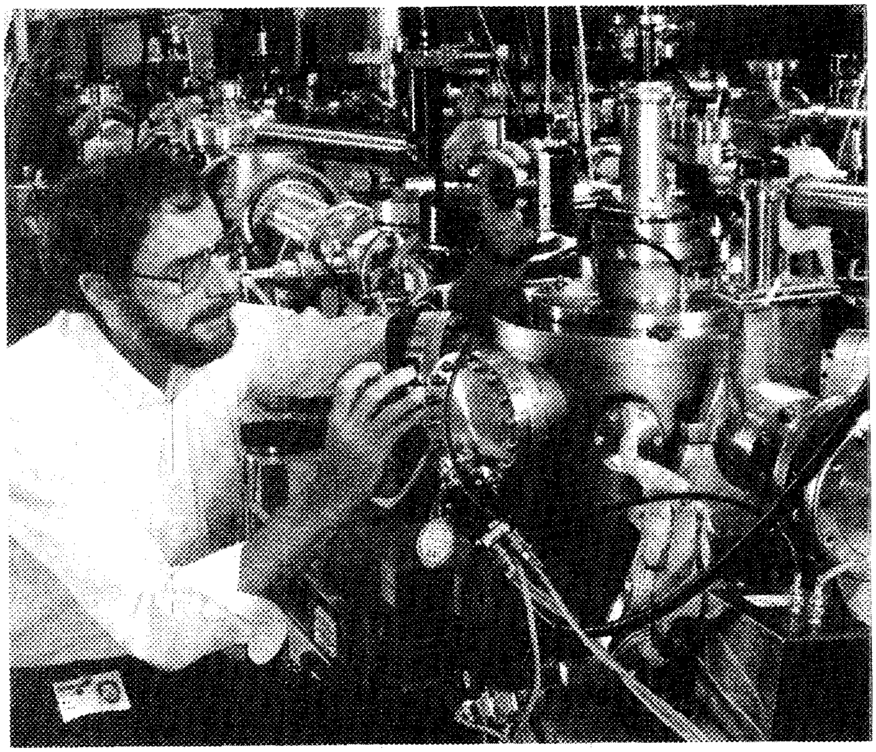


Figure 7.2
An ORNL staff member adjusts the angular orientation of a sample mounted inside a high-vacuum ion-beam deposition chamber. This device is housed at the Surface Modification and Characterization/ Collaborative Research Center, an ORNL user facility.

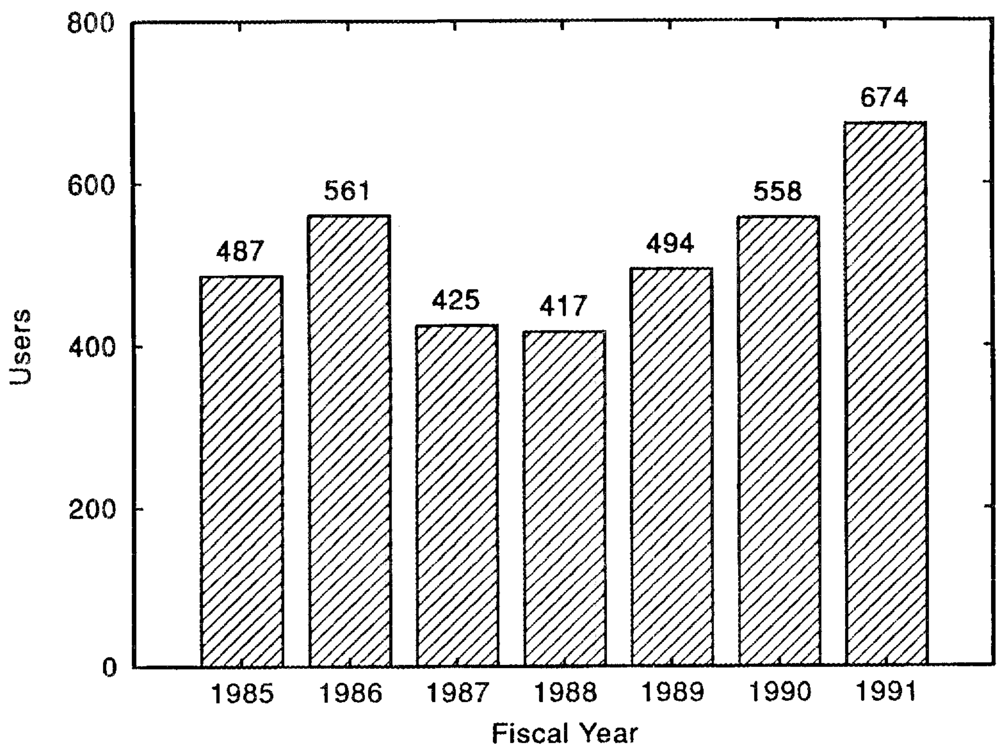


Figure 7.3
Users of ORNL facilities. Numbers do not include ORNL users; ORNL reactor facilities were closed in 1987, 1988, and part of 1989.

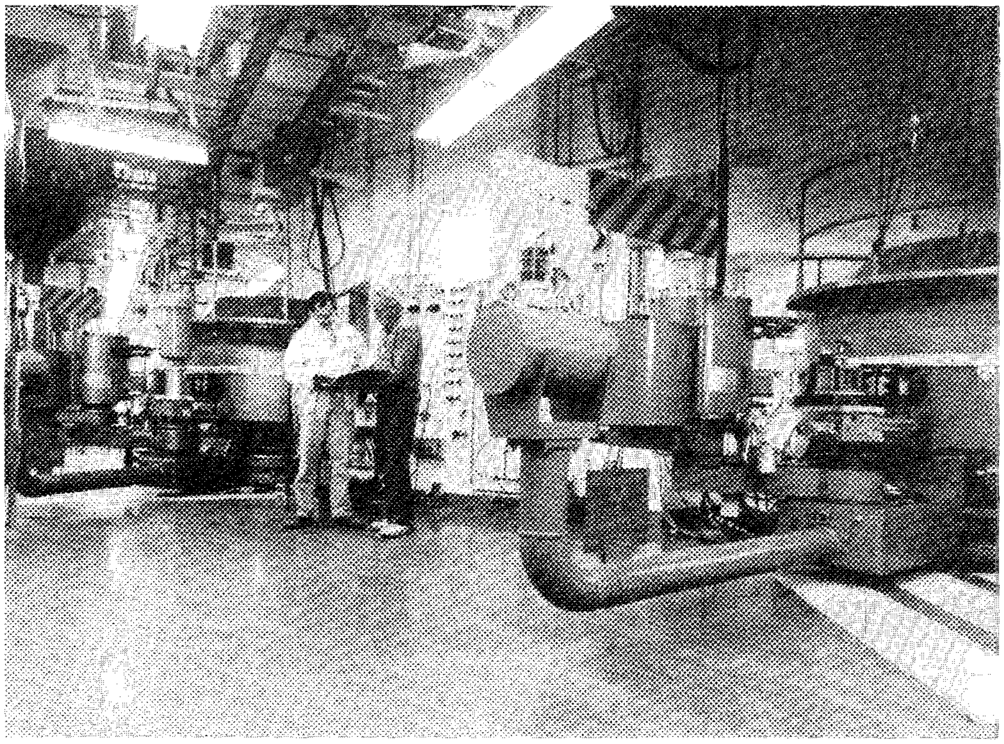


Figure 7.4 The Neutron Scattering Facility, an ORNL user facility. Pictured are the HB-2 and HB-3 triple axis spectrometers in the beam room at the High Flux Isotope Reactor.

Operations Development and Integration Laboratory (MODIL). The objective of the Test Bed is to involve industries, universities, and other federal laboratories in the process of developing and validating new, emerging, and enabling manufacturing technologies. The approval of this facility would expand the scope of the user program and would provide additional opportunities for private-sector participation in Laboratory programs.

Fifty-two new ORNL user agreements were signed during FY 1991 with 32 universities and 20 companies.

Guest Research

Guest scientists are a valuable component of ORNL's research staff. Their assignments, which range from 2 weeks to 2 years, broaden the Laboratory's base of expertise and support its mission of scientific cooperation and technology transfer. In FY 1991 the Laboratory population was augmented by 3690 guest assignments (Fig 7.5), an increase of 250% over the number of assignments 5 years ago. Of this number, 1408 were industrial guests, an increase of 45% over the number assigned in FY 1990 (Table 7.8).

Cooperative Research

Since the ORNL High Temperature Superconductivity Pilot Center Program was initiated in 1989, an increasing number of companies have recognized that a cooperative partnership with the Laboratory can provide access to the significant scientific resources and skills that exist here and that leveraging of research dollars through cost-sharing can be beneficial to both parties. When Energy Systems gained the authority to enter into CRADAs in 1990, the momentum toward joint research projects increased. To date, ORNL has become involved with 32 CRADAs representing commitments of more than $19 million, more than half from the private sector (Table 7.9).

Table 7.6

Experimenters at designated user research facilities in FY 1991

	U.S. Govt. Lab.			University			Industry			Foreign			Total		
	Exp.[a]	Org.[b]	% Use	Exp.	Org.	% Use	Exp.	Org.	% Use	Exp.	Org.	% Use	Exp.	Org.	User days
Holifield Heavy Ion Research Facility (HHIRF)	32	4	46	95	28	50	7	2	0	17	11	4	151	45	4,976
National Environmental Research Park[c]	69	5	55	58	29	37	12	4	8	2	2	0	141[c]	40[c]	4,650[c]
High Temperature Materials Laboratory (HTML)	91	2	58	40	19	7	47	26	35	2	2	0	180	49	9,184
Surface Modification and Characterization Laboratory (SMAC/CRC)	40	6	62	40	21	26	4	4	3	11	8	9	95	39	1,809
Shared Research Equipment (SHaRE)	39	2	80	27	15	15	1	1	0	2	1	5	69	19	924
National Center for Small-Angle Scattering Research (NCSASR)	102	3	49	70	19	35	13	5	5	15	15	11	200	32	2,972
EN Tandem Van de Graaff	31	1	16	74	8	79	0	0	0	3	2	5	108	11	3,972
Oak Ridge Electron Linear Accelerator (ORELA)	27	2	90	1	1	0	0	0	0	4	1	10	32	4	836
Bioprocessing Research Facility	5	1	55	3	2	43	1	1	2	0	0	0	9	4	157
Roof Research Center	10	2	44	2	2	18	22	7	38	0	0	0	32	11	1,005
Neutron Scattering Facility	33	3	43	17	8	23	0	0	0	21	10	34	71	21	1,833
Totals (Experimenters % Use)	**479[d]**		**44[d]**	**427**		**39**	**107**		**10**	**77**		**7**	**1,090**		**32,136**

[a]Experimenters.

[b]Organizations.

[c]The totals for the research park do not include more than 19,000 individuals who participated in the Ecological and Physical Sciences Study Center and the High School HonorsProgram for a total of 5,337 user days in FY 1991.

[d]Includes 416 ORNL users (38% of use).

Table 7.7
Research in ORNL user facilities[a]

Research sector	Fiscal year 1985	1986	1987	1988	1989	1990	1991
University	286	320	264	291	324	337	427
Industry	70	114	41	37	66	84	107
Other government laboratories	64	62	57	51	51	68	77
Foreign Institutions	62	55	47	30	43	69	63
Other	5	10	16	8	10		
Total	**487**	**561**	**425**	**417**	**494**	**558**	**674**

[a]During 1987, 1988, and 1989 several facilities were impacted by the shutdown of ORNL's research reactors.

Figure 7.5
Number of guest assignments at ORNL.

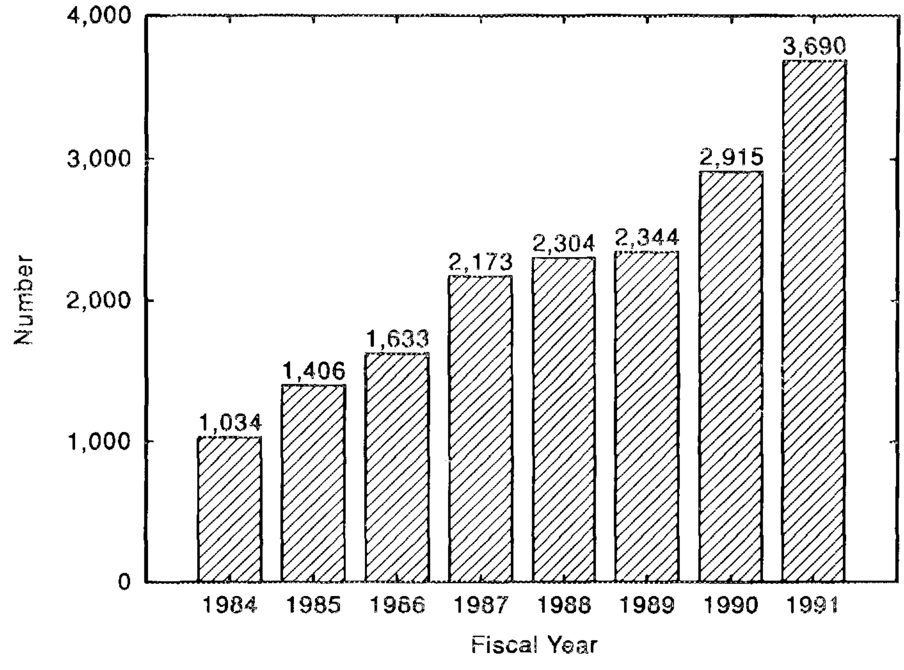


Table 7.8

Number of guest assignments at ORNL[a]

Research sector	Fiscal Year 1984	1985	1986	1987	1988	1989	1990	1991
University	628	920	967	1378	1428	1395	1551	1696
Industry	260[b]	344[b]	398[b]	617	689	736	972	1408
Federal agencies				39	40	52	52	78
Foreign institutions	97	83	77	62	59	48	84	72
Other	49	59	191	77	88	113	256	436
Total	**1034**	**1406**	**1633**	**2173**	**2304**	**2344**	**2915**	**3690**
Increase (%)		36	16	33	6	2	24	27

[a]Guests are nonemployees who come on site to conduct research, to consult, or to perform other services. Users are included in the totals; for example, in FY 1991, 674 of the 3690 guests were users.

[b]Includes federal agencies.

Table 7.9

Examples of CRADA work at ORNL

CRADA partner	ORNL division	Technology
DOW Chemical	Analytical Chemistry	Development of analytical in-line sensors for commercial magnesium electrolysis cell
United Technologies Optical Systems, Inc.	Engineering Technology	Determination of optimum fabrication parameters for silicon-cladded silicon carbide substrates for the production of figured optical surfaces
Electric Power Research Institute, National Institute of Standards and Technology, Ontario Hydro	Energy	Study of the production and mitigation of S_2F_{10}, a toxic by-product formed in electrical discharges in the insulating gas SF_6
Eaton Corporation Johnson Controls	Metals and Ceramics	Development of a high transition temperature nickel-aluminum shape memory alloy material
Society of Plastics Industry and	Energy	Determine the thermal performance of experimental, prototypical foam

Table 7.9
(continued)

CRADA partner	ORNL division	Technology
Polyisocyanurate Insulation Manufacturers Association		insulation boardstock produced by U.S. insulation manufacturers
Cellulose Industry Standards Enforcement Program	Energy	Test the thermal performance of various densities of blown-in cellulose insulation
Science Policy Associates	Energy	Alternative fluorocarbon environmental acceptability study
Garrett (Allied-Signal)	Metals and Ceramics	Microwave annealing of silicon nitride to produce material of improved strength and toughness
Norton Company	Metals and Ceramics	Development of technology for fabrication of heat engine components by reaction-bonded and sintered reaction-bonded silicon nitride processes
Norton Company	Metals and Ceramics	To improve strength and toughness of silicon nitride heat engine components via microwave annealing technology
General Electric	Chemical Technology	Bioremediation of soils and/or sediments contaminated by polychlorinated biphenyls
Appliance Research Consortium, Inc.	Metals and Ceramics	Improve the energy efficiency of residential refrigerator-freezers manufactured by member companies of Appliance Research Consortium, Inc.
Foamseal, Inc.	Energy	Measure the thermal performance of ceiling panels that use a polyurethane adhesive manufactured by Foamseal and used in the construction of manufactured housing
Appliance Research Consortium	Metals and Ceramics	Development of a procedure to predict the lifetime of a powder evacuated panel in dry air
Polyisocyanurate Insulation	Energy	Viability of alternative hyrochloro-

Table 7.9
(continued)

CRADA partner	ORNL division	Technology
Manufacturers Association, U.S. Department of Energy, and the U.S. Environmental Protection Agency		fluorocarbon blowing agents
Microwave Labs	Metals and Ceramics	Develop wideband microwave processing equipment for sintering and other heat treatments
AVX Tantalum Corp.	Metals and Ceramics	Develop a method for microwave sintering tantalum capacitors
Exergy, Inc.	Energy	Test NH_3/H_2O mixtures
Pellissippi International	Health and Safety Research	Optical detection of charged-particle tracks
Eveready Battery Co.	Solid State	Packaging for thin-film lithium microbatteries
General Motors	Metals and Ceramics	Developing improved, longer life, heat resistant, assemblies for heat treating furnaces; work focused on Ni_3Al

8 Human Resources

8 • Human Resources

Policy and Overview

The ORNL Human Resources Division provides human resources direction, leadership, and support in the functional areas of staffing, compensation, training and development, equal employment opportunity/affirmative action (EEO/AA), benefit plans, complaint resolution programs, and personnel relations to Laboratory managers and employees. This is accomplished by being responsive to the policy directives and guidance of Energy Systems, DOE orders, federal regulations, and best management practices.

Characterization, Hiring, and Retention

The diverse nature of the work performed at ORNL requires a high-quality, multidisciplinary technical staff and an equally skilled technical and administrative support staff. The Laboratory's professional staff is composed primarily of scientists and engineers, which represent about 66.6% of the total number (Table 8.1). Of the 732 professional scientists, 468 (64%) hold Ph.D.s; 256 of the 819 engineers on staff (31%) hold Ph.D.s. Master's degrees are held by 551 (24%) of the total professional population at ORNL. About 87% of the total professional staff hold at least a bachelor's degree.

Chemical, mechanical, and nuclear engineers represent the greatest proportion of the professional engineering staff. There are also 32 mathematicians, 410 other physical scientists, 236 life scientists (biomedical and environmental), and 26 social scientists. ORNL is supported by Energy Systems central organizations, including Engineering; C&TD; and Information Resources and Administration, which is composed of library, technical publications, graphic arts, and printing support; and Procurement.

The average age of all ORNL employees is 43.8 years (Fig. 8.1); the average length of company service is 14.3 years. While the average age has remained relatively stable since 1986 at 43.2 years, an increasing rate of retirement among the total population has caused the average length of service to decrease from 15.4 years. In 1991, 519 new employees were added to the staff while there were only 422 separations, resulting in an addition rate of 9.5% and a separation rate of 7.8%. The 1990 addition rate was 8.8%, and the separation rate was 9.0%.

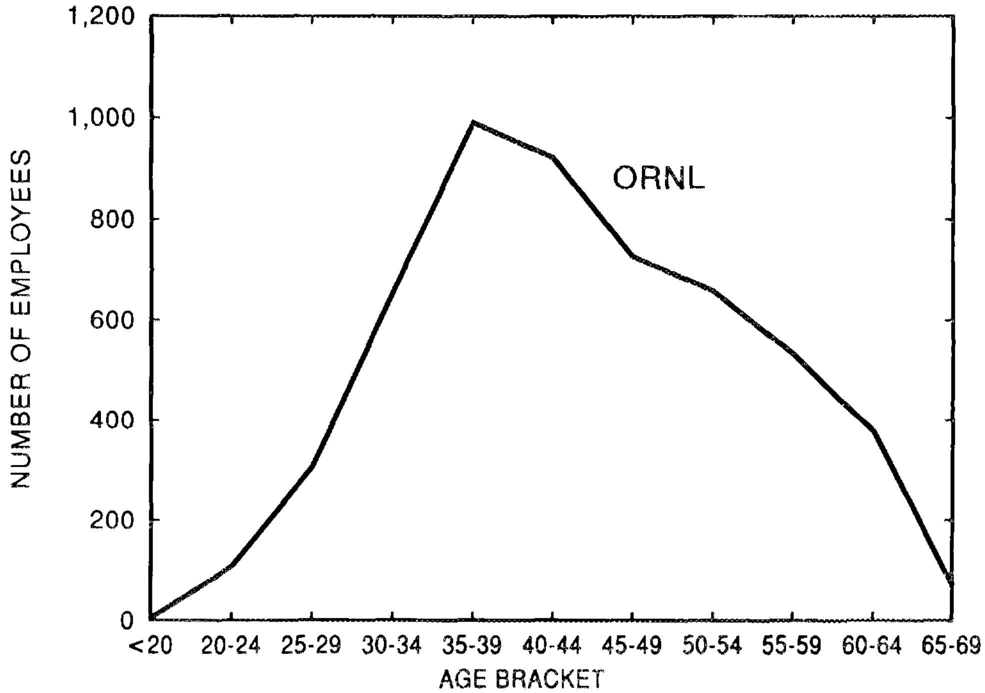
The Laboratory had a 77.3% acceptance rate for employment offers made to Ph.D. applicants during 1991, an increase from 76.6% in 1990. The competition for outstanding scientists and engineers continues to increase. As a result, an increased emphasis has been placed on recruiting at leading colleges and universities, job fairs, and professional meetings. The Laboratory is also using educational "seed" programs, increasing its targeted print advertising in professional journals and magazines, and has enhanced its marketing efforts to attract women and minorities. Further, every effort is employed to offer competitive salaries and benefit packages. To ensure the continued high caliber of those

Table 8.1
ORNL staff composition (CY 1991)[a]

	Ph.D	MS/MA	BS/BA	AS	Non Degreed	Total
			Professional staff			
Scientists	468	133	113	4	14	732
Engineers	256	241	254	8	60	819
Management/administrative	118	100	124	2	46	390
Other	30	77	117	16	148	388
Total professional staff	**872**	**551**	**608**	**30**	**268**	**2329**
			Support staff			
Technicians	0	4	84	110	325	523
Union employees (includes crafts, laborers, etc.)	0	1	8	22	956	987
Administrative/clerical	0	1	66	58	586	711
Other (i.e., supervisors of union employees)	0	0	4	9	79	92
Total support staff	**0**	**6**	**162**	**199**	**1946**	**2313**
Laboratory total staff	**872**	**557**	**770**	**229**	**2214**	**4642**

[a]Includes full-time regular employees.

Figure 8.1
ORNL aging curve



being hired, the Laboratory has established hiring guidelines that define the academic and professional characteristics being sought in new hires. An ad hoc review process has been reinstituted for prospective employees having Ph.D.s and for experienced B.S. and M.S. technical candidates.

To ensure continuity in both staff quality and capability, the Laboratory recognizes that it is necessary not only to attract and hire outstanding personnel but also to retain them (Table 8.2). ORNL strives to provide a suitable environment for research, to provide opportunity for growth, and to reward excellent performance. Several financial and nonfinancial incentive and recognition programs have been established to reward outstanding contributions and significant achievements. The Special Achievement Awards Program is a financial incentive program that recognizes employee contributions at two levels in the organization.

Table 8.2
Affirmative Action and Equal Employment Opportunity

Full-time regular and continuing part-time employees	Calendar year 1986				Calendar year 1991			
	Male	Female	Total	%	Male	Female	Total	%
White	2977	1062	4039	89.5	2978	1148	4126	89.7
Black	202	149	351	7.8	201	134	335	7.3
Hispanic	22	5	27	0.6	25	6	31	0.7
Asian or Pacific Island	72	19	91	2.0	77	25	102	2.2
American Indian or Alaskan native	3	2	5	0.1	2	4	6	0.1
Total minorities	299	175	474	10.5	305	169	474	10.3
Total employees	3276	1237	4513	100	3283	1317	4600	100
Foreign Nationals[a]			73				57	

[a]Includes full-time regular and temporary employees.

At the division level, individuals are rewarded for overall quality of sustained performance; and at the facility or major organization level, employees are selected based on the achievement of special goals, milestones, and/or assignments of substantial impact on organizational programs. Another program pays Energy Systems inventors for technology developed, patented, and transferred to private industry.

ORNL participates in the Energy Systems annual awards night, which recognizes outstanding performance in various categories. These include publications, technical achievement, management support service, inventions, operational performance, and administrative/technical support. Special achievements and accomplishments of ORNL employees are also recognized through announcements in a variety of in-house publications (*Energy Systems News, Lab Notes, Inside Line*). Other incentives include participation in professional organizations and meetings, sabbatical leave, and other work-related travel.

Affirmative Action and Equal Employment Opportunity

Numerous studies have addressed the changing demographics of the country's work force, especially as it relates to those being trained in the sciences, and have suggested that a more culturally diverse work force is on the horizon. As more of these workers enter the job market, it will be necessary for personnel managers to adopt less traditional approaches. Projections show that by the year 2000, over one-half of those entering the work force will be women, minorities, and the disabled. The Laboratory and Energy Systems are already instituting changes in personnel policies that will be required to meet the different demands of this changing work force. For example, the company's part-time policy and the concept of employee convenience time both allow employees greater flexibility in scheduling work hours.

Expansion of management skills is being addressed through a formal cultural diversity training program, increased accountability for equal employment opportunity (EEO) and affirmative action (AA) program components, and responsibility for employee development plans for minorities. ORNL has established a management/employee-oriented EEO Strategic Plan Implementation Committee to develop strategies for ORNL to meet its own and other Energy Systems EEO/AA challenges. Additional work force issues are also being identified and considered by an Energy Systems and Martin Marietta Corporate task force.

As access barriers fall and technology evolves, disabled Americans are expected to assume a greater role in the future work force of ORNL (Fig. 8.2). The Laboratory will continue its heightened emphasis on recruiting and hiring qualified disabled candidates. Plans for recruiting and hiring the handicapped and disabled and Vietnam-era veterans are developed and implemented annually from the EEO/AA office at ORNL.

Energy Systems President Clyde Hopkins has appointed a special assistant to serve on the Executive Committee of the (U.S.) President's Committee on the Employment of People with Disabilities to provide leadership in this area. Energy Systems recognizes the potential for significant overall change in our disability program relative to passage of the 1990 Americans with Disabilities Act. The ORNL Disability Program Oversight Committee was formed in 1991 to implement requirements of the Americans with Disabilities Act and to ensure compliance with new policies and procedures relating to the legislation.

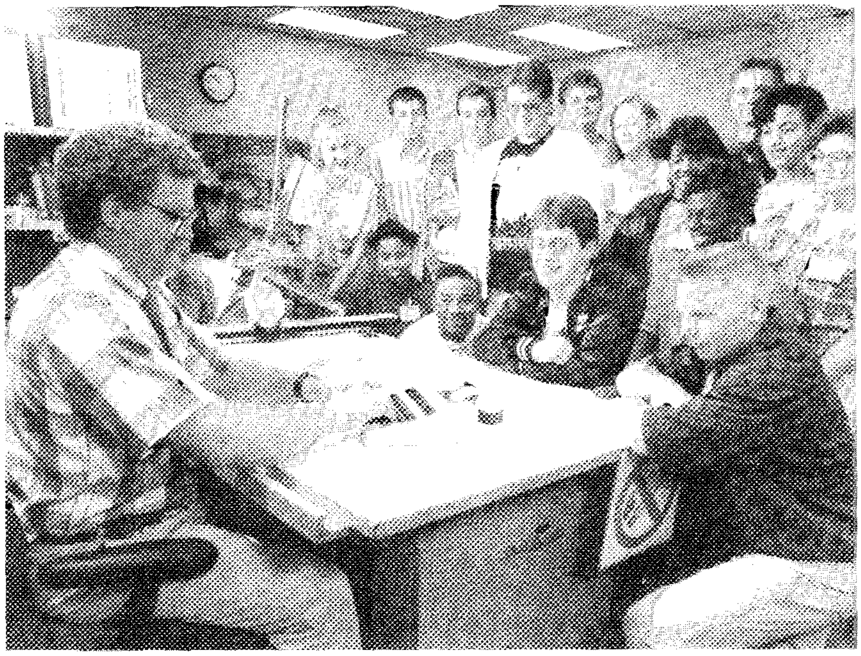


Figure 8.2 Danny Cochran, a hearing-impaired employee in the ORNL Chemical Technology Division, demonstrates his telecommunications device for the deaf and talks with American Sign Language Class students from Alcoa High School.

AA is an integral part of all personnel functions and activities for the Laboratory. The ORNL AA office is a department within the Human Resources Division, and the AA program site manager reports directly to the ORNL human resources director. A primary responsibility for the AA program site manager is to monitor AA activities and to inform Laboratory management about progress made in hiring, promoting, and developing minorities, women, people with disabilities, and Vietnam-era and disabled veterans. The site manager also monitors and keeps management aware of areas of concern relative to the program, such as the inability to meet a hiring goal or to maintain on-staff representation of minorities or of women at the calculated availability. The AA site manager is responsible for creating and promoting a variety of programs and events to recognize minority groups and individuals, including Martin Luther King, Jr., birthday observances; Asian Pacific Heritage Week; Black History Month; and Hispanic Heritage Month. The manager is also responsible for promoting the importance, benefits, and economic advantages of having a culturally diverse work force. Also as part of the EEO/AA office, ORNL employs a full-time salaried employee complaint counselor. The counselor works with staff and management to resolve a variety of employee issues and complaints, including allegations of discrimination and sexual harassment. Overall, the Laboratory's representation of minorities has remained fairly constant (Tables 8.3 and 8.4). The representation of women on staff has continued to increase with a concomitant increase in upward mobility; the number of women being promoted to higher levels and into management is growing.

Upward mobility for minorities is receiving special attention from Laboratory management. The Laboratory has undertaken additional recruiting efforts to increase the size of the pool from which minority candidates for management openings can be drawn. Plans are being prepared for salaried minorities in an effort to identify areas for growth and development. Also, the formal mentor program, although it makes no guarantees of promotion, can provide increased visibility for an employee, either within his or her own area of work or outside of it, depending on the mentor selected. In 1992, at least 20 ORNL employees, primarily women and minorities, will participate in the program, which provides an opportunity for each participant to become better acquainted with the larger Energy Systems organization. Further, it is hoped that through the interactions necessitated by these mentorships, employees will gain additional insights that will be useful in developing their own career plans.

Training and Education

Among the the special personnel programs sponsored by the Laboratory, the Educational Assistance Program remains an effective tool for helping employees achieve their academic and career goals. In 1991, over 434 employees participated in this program. The program helps ensure the proper availability, optimum utilization, and continuing welfare of Laboratory employees.

The Laboratory also provides in-house development programs designed to meet the specific education and training needs of its current population. Further, the Laboratory is responding to a heightened emphasis on ES&H issues as well as other cultural and social issues affecting employees and management by expanding specialized training programs such as sexual harassment training and nonsmoking clinics. Finally, the curriculum of courses offered as a part of ORNL's management training is being expanded to include courses that present strategies for communicating across cultural barriers and for appreciating cultural diversity. This area of management training is crucial in preparing managers for the changing work force of the 1990s.

Table 8.3

ORNL equal employment opportunity statistics (CY 1986)

			Male					Female				
Occupational codes	Total	Minority total (%)	White (%)	Black (%)	Hispanic (%)	Native American (%)	Asian (%)	White (%)	Black (%)	Hispanic (%)	Native American (%)	Asian (%)
Officials and managers	493	20 (4.1)	435 (88.2)	13 (2.6)	0 (0.0)	0 (0.0)	4 (0.8)	38 (7.7)	3 (0.6)	0 (0.0)	0 (0.0)	0 (0.0)
Professionals	1734	151 (8.7)	1305 (75.3)	32 (1.8)	13 (0.7)	1 (0.06)	67 (3.9)	278 (16.0)	21 (1.2)	1 (0.06)	1 (0.06)	15 (0.9)
Technicians	602	48 (8.0)	443 (73.5)	25 (4.2)	8 (1.3)	0 (0.0)	0 (0.0)	111 (18.4)	13 (2.2)	1 (0.2)	0 (0.0)	1 (0.2)
Office and clericals	713	100 (14.0)	32 (4.5)	7 (1.0)	0 (0.0)	1 (0.1)	0 (0.0)	581 (81.5)	87 (12.2)	3 (0.4)	0 (0.0)	2 (0.3)
Craft workers	549	26 (4.7)	514 (93.6)	25 (4.6)	0 (0.0)	1 (0.2)	0 (0.0)	9 (1.6)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Operators	179	50 (27.9)	114 (63.7)	40 (22.3)	1 (0.6)	0 (0.0)	1 (0.6)	15 (8.4)	8 (4.5)	0 (0.0)	0 (0.0)	0 (0.0)
Laborers	95	36 (37.9)	49 (51.6)	29 (30.5)	0 (0.0)	0 (0.0)	0 (0.0)	10 (10.5)	7 (7.4)	0 (0.0)	0 (0.0)	0 (0.0)
Service workers	148	43 (29.1)	85 (57.4)	31 (20.9)	0 (0.0)	0 (0.0)	0 (0.0)	20 (13.5)	10 (6.8)	0 (0.0)	1 (0.7)	1 (0.7)
Total	4513	474 (10.5)	2977 (66.0)	202 (4.5)	22 (0.5)	3 (0.07)	72 (1.6)	1062 (23.5)	149 (3.3)	5 (0.1)	2 (0.04)	19 (0.4)
Foreign nationals[a]	73											

[a]Includes full-time regular and temporary employees.

Table 8.4

ORNL equal employment opportunity statistics (CY 1991)

Occupational codes	Total	Minority total (%)	Male					Female				
			White (%)	Black (%)	Hispanic (%)	Native American (%)	Asian (%)	White (%)	Black (%)	Hispanic (%)	Native American (%)	Asian (%)
Officials and managers	501	25 (4.9)	441 (88.0)	19 (3.8)	0 (0.0)	0 (0.0)	4 (0.8)	35 (7.0)	1 (0.2)	0 (0.0)	0 (0.0)	1 (0.2)
Professionals	1896	166 (8.8)	1420 (74.9)	40 (2.1)	16 (0.8)	1 (0.05)	70 (3.7)	310 (16.4)	23 (1.2)	1 (0.05)	1 (0.05)	14 (0.7)
Technicians	524	44 (8.4)	342 (65.3)	23 (4.4)	7 (1.3)	0 (0.0)	0 (0.0)	138 (26.3)	11 (2.1)	0 (0.0)	0 (0.0)	3 (0.5)
Office and clericals	697	88 (12.6)	18 (2.6)	4 (0.5)	0 (0.0)	0 (0.0)	0 (0.0)	591 (84.8)	73 (10.5)	5 (0.7)	1 (0.1)	5 (0.7)
Craft workers	554	35 (6.3)	505 (91.1)	31 (5.6)	1 (0.2)	1 (0.2)	2 (0.4)	14 (2.5)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Operators	178	48 (27.0)	112 (62.9)	39 (21.9)	1 (0.6)	0 (0.0)	1 (0.6)	18 (10.1)	7 (3.9)	0 (0.0)	0 (0.0)	0 (0.0)
Laborers	84	24 (28.6)	45 (53.6)	18 (21.4)	0 (0.0)	0 (0.0)	0 (0.0)	15 (17.9)	6 (7.1)	0 (0.0)	0 (0.0)	0 (0.0)
Service workers	166	44 (26.5)	95 (57.2)	27 (16.3)	0 (0.0)	0 (0.0)	0 (0.0)	27 (16.3)	13 (7.8)	0 (0.0)	2 (1.2)	2 (1.2)
Total	4600	474 (10.3)	2978 (64.7)	201 (4.4)	25 (0.5)	2 (0.04)	77 (1.7)	1148 (25.0)	134 (2.9)	6 (0.1)	4 (0.09)	25 (0.5)
Foreign nationals[a]	57											

[a]Includes full-time regular and temporary employees.

9 Site and Facilities

9 • Site and Facilities

Laboratory Description

ORNL is a large, multiprogram energy research laboratory with projects that cover diverse scientific and engineering disciplines. These programs create demands for a variety of building and equipment needs, including specialized experimental laboratories and a large complement of office space. Along with these are needs for major utility and waste-disposal facilities. In addition, the ever changing description and set of programs that result from the nature of developmental research and evolving national energy priorities require a high degree of flexibility in the use of the Laboratory's facilities.

Currently, the Laboratory occupies ~2.6 million ft^2 of building space at the main Bethel Valley site and the Melton Valley site to the south. In addition, over 1 million ft^2 of building space at the Oak Ridge Y-12 Site are allocated to the Laboratory, and ~200,000 ft^2 of space are occupied by ORNL personnel at the Oak Ridge K-25 Site.

ORNL has full responsibility for facilities at its main site and in the surrounding areas. However, for the facilities at the Y-12 and K-25 sites, ORNL has full responsibility for building maintenance but only limited responsibility for supporting utilities.

In recent years, continued growth in ORNL staff, visiting researchers, and guests, along with the transfer of a number of DOE personnel to the Laboratory site, has forced the use of many temporary trailer facilities (~50,000 ft^2) as well as the use of local off-site rental space (~60,000 ft^2).

Because the Laboratory site and facilities were originally developed as part of the Manhattan Project and have evolved to the present under insufficient facility modernization budgets to permit needed building replacement, the average age of Laboratory buildings has been steadily increasing, and the condition of building space and supporting utilities has been declining. Figures 9.1 through 9.6 illustrate the current distribution, use age, condition, and size of ORNL buildings. Table 9.1 lists estimated facility replacement values. The replacement estimates are based on currently active functions and do not include replacement of obsolete facilities or costs associated with decontamination and decommissioning (D&D) of existing facilities.

Although past funding limitations have not permitted major upgrades over large portions of the Laboratory site, some of the least desirable space has been replaced through construction projects supported by GPP funds. Also, past approval of a limited number of major line-item requests has permitted construction of some important new research buildings and significant restoration of utility systems. Ongoing projects to upgrade waste management capabilities and DOE-budgeted projects for a new office building and re-roofing work to begin in FY 1993 will provide much-needed improvements. However, more must be accomplished to provide the kind of facilities conducive to producing the highest quality research programs.

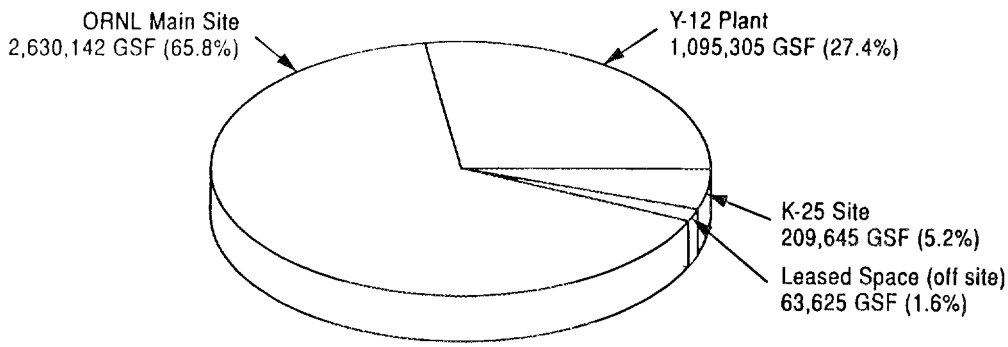


Figure 9.1
Laboratory space distribution—location and building area in gross square feet (GSF)

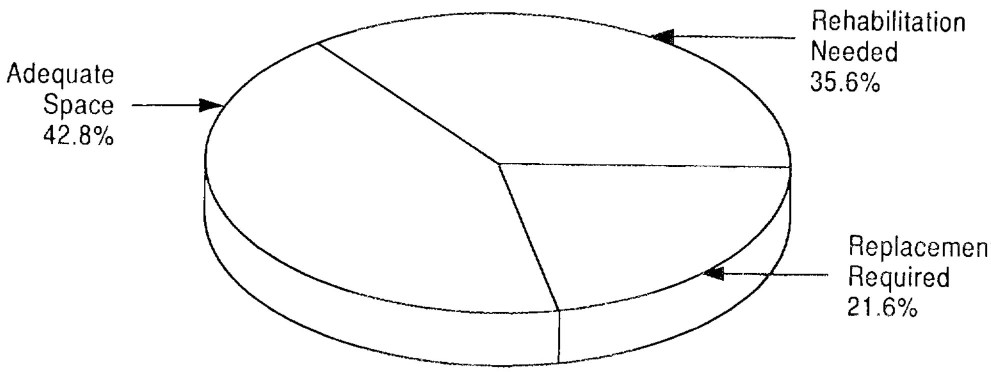


Figure 9.2
Condition of Laboratory space by percentage

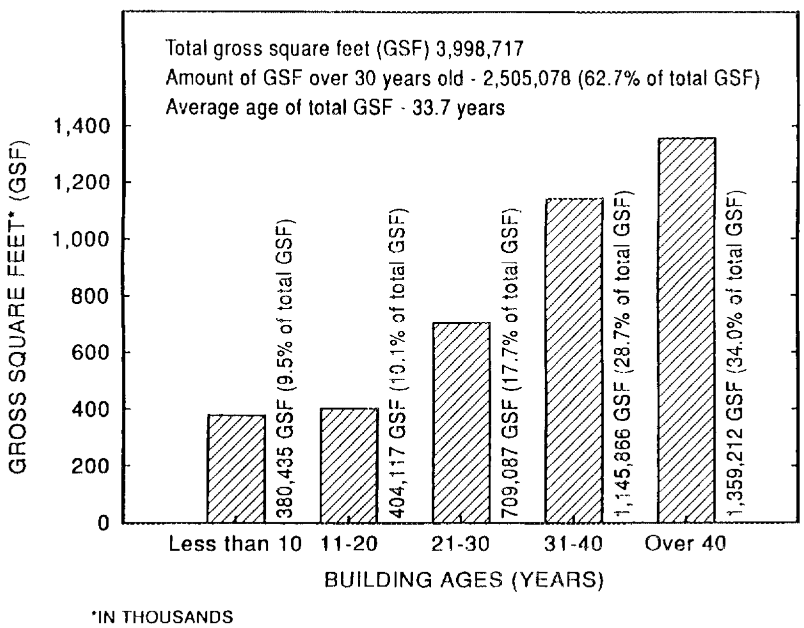
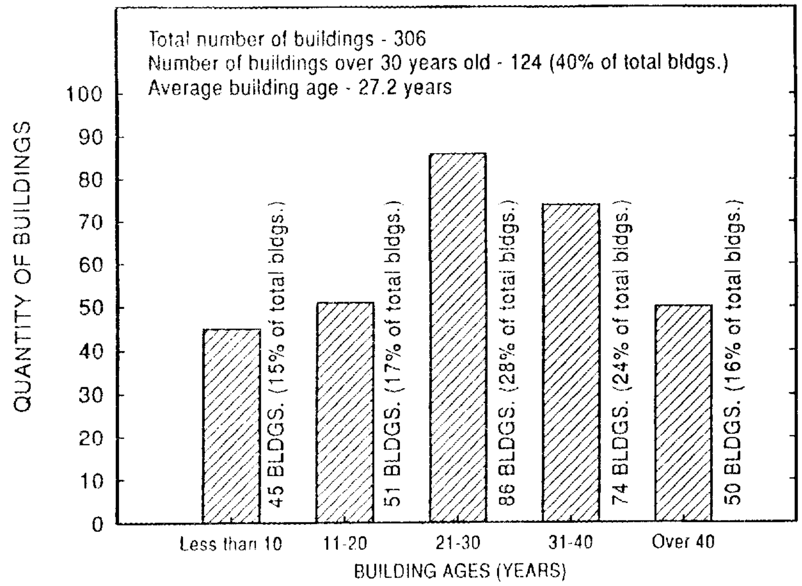


Figure 9.3
Gross square footage of Laboratory buildings—categorized by age

Figure 9.4
Distribution of Laboratory buildings by age



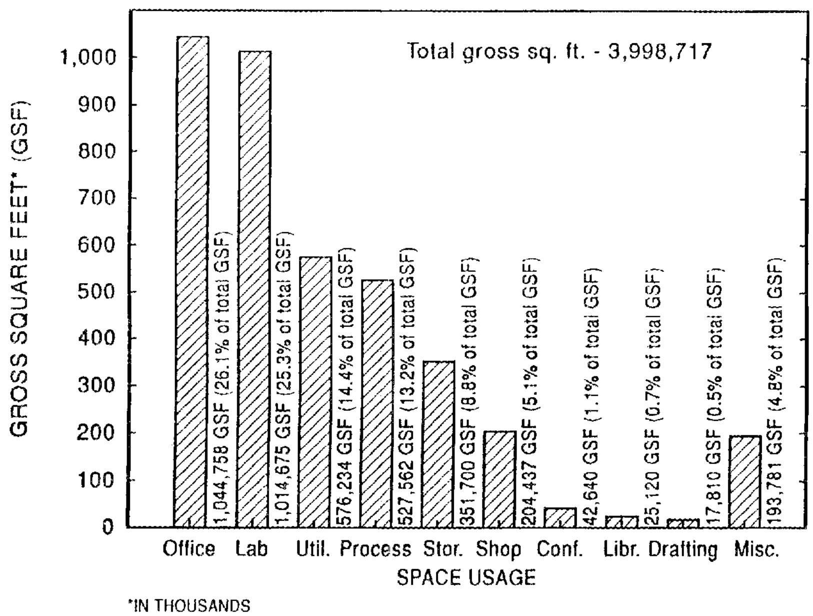
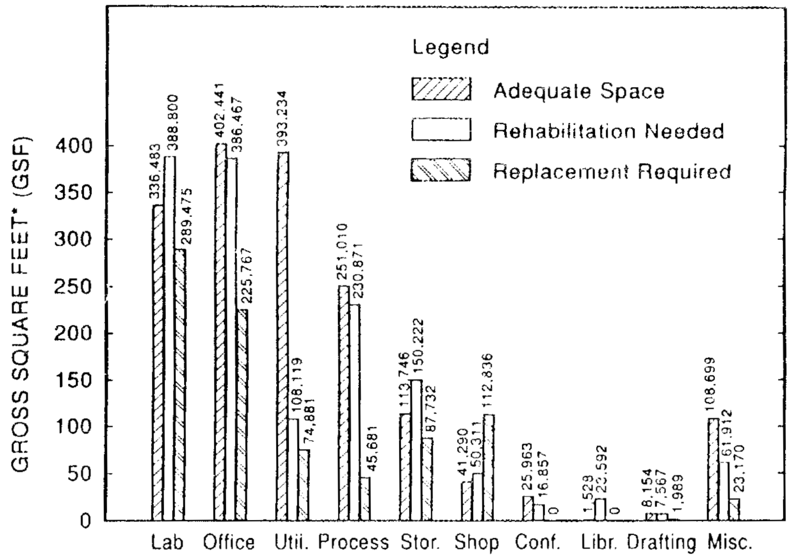


Figure 9.5
Use of Laboratory space

In addition, over the years ORNL has employed a number of major experimental facilities to conduct its programs. Nuclear reactors, radioisotope production facilities, and centrifuge enrichment facilities have supported many important aspects in the development of this nation's nuclear energy, nuclear medicine, and research capabilities. Now that the useful life of some of these facilities has been expended, the Laboratory is faced with significant expense for current surveillance activities and eventual D&D. A major funding commitment will be required to properly dispose of these inactive facilities.

A major concern is that DOE funding support for all forms of nonenvironmental capital projects and equipment has declined significantly over the last several years. Figure 9.7 shows that funding for nonenvironmental capital improvements at ORNL has declined by 48% between FY 1984 and FY 1992.

Figure 9.6
Condition of Laboratory space— categorized by use



*IN THOUSANDS

Table 9.1
Estimated facilities replacement values

Facilities type	Replacement cost range[a] Lower	Upper
Buildings and structures	730	1,032
Reactors	1,300	1,650
Process facilities	480	725
Accelerators	285	430
Utility systems	240	350
Roads, bridges, and parking	143	176
Security facilities	6	11
Automatic data-processing equipment	66	93
Motor vehicles	11	17
Heavy equipment	6	11
Other equipment and facilities	33	55
Subtotal, fixed price construction	**3,300**	**4,550**
Engineering (35%)	1,163	1,593
Construction support services (20%)	660	910
Operation readiness review (2.5%)	82	114
Construction manager (15%)	495	683
Subtotal	**5,700**	**7,850**
Contingency (40%)	2,300	3,150
Total	**8,000**	**11,000**

[a]In millions of FY 1992 dollars.

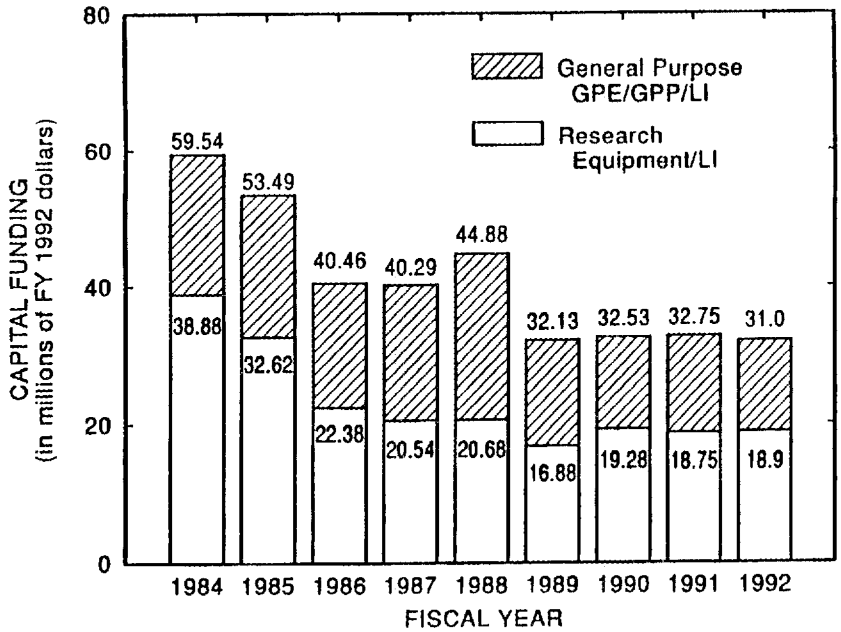


Figure 9.7
Recent capital-funding levels for nonenvironmental capital improvements at ORNL

Facilities Plans and Options

The objectives of ORNL's site and facilities development plans are to provide high-quality space, reliable utility support, and the additional necessary infrastructure required to produce the appropriate environment for conducting outstanding research on DOE programs. To achieve this goal, it is crucial that capital assets planning be closely coupled to the Laboratory's technical program objectives and plans as described in this document.

In response to recognized national needs, the Laboratory's strategic directions have been set to address three primary themes:

- energy R&D,
- environmental studies, and
- improved competitiveness of the United States in the international marketplace.

In support of both energy R&D activities and improved U.S. competitiveness, three major programmatic facilities are required:

- the ANS to serve as the world's most powerful neutron research facility;
- the Center for Biological Sciences to establish an efficient, consolidated research center for biology programs; and
- the MS&E Complex to provide state-of-the-art research facilities for materials programs.

All three of these facilities will include a strong focus on technology transfer through establishment of user facilities and educational activities through joint programs with universities.

Another major facility required for environmental protection purposes is the Waste Handling and Packaging Plant. This facility will conduct radioactive waste solidification operations and packaging for shipment to the national disposal site.

The Laboratory has placed high priority on two other new building projects: a Center for Computational Science to provide a first-class computing capability to support research programs and a Center for Education and Technology Transfer to establish improved links with both educational institutions and private industry while simultaneously providing training facilities for ORNL staff.

Finally, a major new project is proposed to allow extensive renovations and rehabilitation of general-purpose buildings and utility systems that have gradually deteriorated for more than 40 years. The multiprogram, general-purpose facilities section of Table 9.2 shows specific line-item requests supporting this initiative. This initiative must be supplemented with a vigorous program to dispose of inactive experimental facilities that have exceeded their useful life and that currently require continual surveillance to ensure safe shutdown. These inactive facilities include obsolete research reactors, former isotope production facilities, and former biological research facilities. We anticipate eventual D&D of the reactor and isotope facilities as part of DOE's Surplus Facilities Program. Several options are being studied for deposition of biological research facilities, including transfer for use as part of Y-12 Plant weapons programs, potential use for other expanded weapons activities at Oak Ridge, or demolition under DOE's proposed facilities modernization initiative.

Siting of all ORNL's proposed construction projects is described in the *ORNL Site Development Plan*. In broad terms, this plan adheres to a concept that locates new buildings with existing structures in ways that lead to functional groupings like the Life Sciences Complex and the Materials Science and Engineering Complex.

General-Purpose Facilities Plan

The Laboratory's general-purpose facilities plans are reflected in proposals for (1) multiprogram general-purpose facility line items, (2) general plant projects, and (3) general-purpose equipment. As is described in the previous section entitled "Facilities Plans and Options," a major new project is proposed for restoration of general-purpose infrastructure. The proposed line-item construction projects supporting this project are listed in Table 9.2. The associated requirements for general plant projects and general-purpose equipment (GPE) are given below.

General Plant Projects

Funding for GPPs plays a key role in allowing the Laboratory to implement small construction projects (less than $1.2 million each) required to support Laboratory operations. These projects are of a general-purpose nature and include alterations, renovations, and new construction. They are extremely important to continuing operations when long-term budgeting requirements cannot be foreseen. ORNL is requesting funds from landlord programs under the Assistant Secretary for Environmental Restoration and Waste Management and the DOE Office of Energy Research, which total the levels shown in Table 9.3.

General-Purpose Equipment

GPE support is the only source of funds for supplying the Laboratory support and service divisions with badly needed capital resources (Table 9.4). For many years, the GPE funding level has been insufficient to maintain a modern research facility. ORNL has relied heavily on receipt of these funds to provide critical replacements. ORNL is currently experiencing an equipment request backlog exceeding $13 million for FY 1992. Items not funded in FY 1992 will still be required and thus added to FY 1993 funding requirements. ORNL receives about $3 million annually for GPE of about $8 million to 9 million required for maintenance of continuing needs. Typical types of capital equipment procured with GPE funds include the replacement of underground storage tanks, vehicles, shop and maintenance equipment, personnel- and environmental-monitoring equipment, computers, test equipment, security and fire protection needs, and other items related to the general operation and upkeep of ORNL. Table 9.5 provides a description of ORNL's capital equipment investment and its associated annual replacement requirements.

Table 9.2

Major construction projects[a]

($ in millions)

	FISCAL YEAR								
	Funded construction		Budgeted construction	Proposed construction					Total estimated cost
	1991	1992	1993	1994	1995	1996	1997	1998	
Research program line-item projects[b]									
Solid State Research Facility		3.0							3.0
Upgrade neutron-scattering instrumentation				3.3	4.8	4.4			12.5
Advanced Neutron Source (design only)				43.2	56.4				99.6
Advanced Neutron Source (construction)					32.2	168.5	359.5	600.2	2119.6
Center for Biological Sciences				16.0	41.0	39.5			96.5
Upgrade Radiochemical Development Facility ventilation and containment						8.0	14.0	12.0	42.0
Earth Systems Facility						2.0	10.0	7.0	19.0
Center for Study of Advanced Materials						2.0	8.0	7.0	17.0
Biological Imaging and Photonics Laboratory						1.5	6.5		8.0
Center for Advanced Microstructural Analysis							5.0	14.0	41.0
Composite Materials Laboratory							c	c	30.0
Solid State Research and Processing Science Center							c	c	28.0
Environmental restoration and waste management projects									
Bethel Valley LLW-CAT system upgrade (WBS 3.37)	7.1	1.0	0.0	6.5	17.0	6.0	5.0		65.0
Upgrade process waste treatment system		4.7		1.3					6.0
Melton Valley LLW-CAT system upgrade (WBS 3.45)		4.5	15.9	11.5	9.1				41.0
Upgrade sanitary sewer system			2.0	7.0	7.0				16.0
Bethel Valley FFA Upgrades				6.0	6.5	6.5	1.5		20.5
Waste Characterization and Certification Facility (WBS 4.48)				2.0	5.5	8.5	2.0		18.0
MVST Capacity Increase (WBS 3.46)				9.4	22.0	11.0	5.6		48.0
Process Waste-Treatment Facility						2.0	13.0	10.0	25.0
Retrievable Cask Storage Bunker						1.5	4.5		6.0
Waste Handling and Packaging Plant							11.5	45.3	270.0

Table 9.2 (continued)

	FISCAL YEAR								
	Funded construction		Budgeted construction	Proposed construction					Total estimated cost
	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	
Multiprogram general-purpose facilities (KG)									
Buildings facilities/revitalization									
A. Replace substandard housing									
Measurements and Controls Support Facility	3.1	0.3	0.5						4.73
Central Research and Support Building			4.4	7.0	1.0				12.4
Environmental, Safety, and Health Compliance and Training Facility				5.2	6.4				11.6
Central Maintenance Support and Quality Testing Facility							3.0	9.0	18.0
Decontamination Laundry								2.0	10.0
Safeguards and Security Building								3.0	16.0
B. Renovate serviceable structures									
Replace deteriorated roofing, priority 1			5.0	6.0	4.0				15.0
Replace deteriorated roofing, priority 2					4.0	8.0	6.0		18.0
Replace deteriorated roofing, priority 3							4.0	7.0	16.5
Upgrade building HVAC systems, ORNL at the Y-12 Plant							4.0	2.0	6.0
Upgrade building HVAC systems, east end								5.0	20.0
Upgrade building HVAC systems, west end									15.0
Restore Central Research Complex									80.0

Table 9.2 (continued)

	FISCAL YEAR								
	Funded construction		Budgeted construction	Proposed construction					Total estimated cost
	1991	1992	1993	1994	1995	1996	1997	1998	
C. New capabilities									
Advanced Computing Technology Center							3.0	8.0	17.0
Center for Education and Technology Transfer								4.0	21.0
Environmental, safety, and health protection									
A. Environmental protection									
Steam plant environmental improvements							4.0	9.0	19.0
B. Safety									
Fire protection upgrade	2.0	1.4							4.7
OSHA compliance facility upgrades				2.2	4.5	3.8			10.5
Utility restorations									
Upgrade electrical system	1.45	0.01							2.3
Upgrade steam distribution system, west end		1.08	5.61	2.31					9.0
Upgrade water system						4.0	12.0	12.0	30.0
Upgrade primary electrical distribution system							3.0	8.0	18.0

[a] Construction data as of September 1992.
[b] Does not include accelerator and reactor improvements and modifications projects or New Production Reactor construction funding.
[c] To be determined.

Table 9.3

General plant project funding from landlord programs
($ in millions—BA)

	FISCAL YEAR						
	1992	1993	1994	1995	1996	1997	1998
Funding	7.7	7.0	12.5	20.0	20.0	20.0	20.0

Table 9.4

General-purpose equipment funding from landlord programs
($ in millions—BA)

	FISCAL YEAR						
	1992	1993	1994	1995	1996	1997	1998
Funding	3.0	8.6	10.6	10.0	10.0	7.0	7.0

Table 9.5

Capital equipment investment and age

FIS asset code	Asset code description	Current asset value[a] $(000)	% Depreciated	Average useful life (years)	Estimated annual replacement expense[b] $(000)
610	Communication System	3,683	27	12	404
620	Fire Alarm System	631	100	25	25
710	Heavy Mobile Equipment	3,681	73	10	368
715	Hospital & Medical	422	41	10	42
720	Lab Equipment	122,384	49	20	6,119
725	Motor Vehicles & Aircraft	8,434	63	10	843
730	Office Furniture	3,174	57	10	317
735	Process Equipment	22,694	49	25	907
740	Railroad Rolling Stock	0	0	0	0
750	Security & Protection Equip.	301	35	15	20
755	Shop Equipment	18,733	52	20	936
760	Reserve Construction Equip.	0	0	0	0
770	Automated Data Processing	45,349	64	7	6,478
799	Miscellaneous Equipment	3,604	48	10	369
		233,090			16,819
	Current GPE Funding Level:	3,000			
	Proposed GPE Funding Level:	8,623			

[a]Total, uninflated orginal cost.
[b]Total inflated orginal cost divided by average useful life.

Inactive Surplus Facilities Plan

A significant number of facilities at ORNL are currently inactive or are expected to become inactive in the next several years. These facilities are either no longer needed for their original purpose or are old and deteriorating to the point that continued upkeep as operational facilities is not cost-effective. A large number of these facilities are also contaminated with radioactive or hazardous materials and have no programmatic support from DOE. At the present time, the expense of S&M for these surplus facilities is borne by division or Laboratory overhead. As a result, research programs are indirectly financing the cost of ensuring adequate containment, and mission-oriented R&D activities are cut back proportionately to provide the necessary funding.

A Laboratory-wide survey was conducted in late FY 1991 to scope the number of facilities expected to become surplus in the near term and to determine the estimated annual cost for S&M. The number of facilities in this category and the estimated annual expense are shown in Tables 9.6 and 9.7 respectively. These results indicate that some 80 individual facilities are expected to be surplus by FY 1995, with a conservative estimate of annual expenditure for S&M of $6.5 million in that year. These costs do not include the cost of eventual D&D, which is expected to be orders of magnitude higher.

Many of the facilities identified in the survey can be prepared for and submitted to the DOE Environmental Restoration (EM) D&D Program. Once accepted and transferred, that program then assumes the costs for continued S&M as well as final D&D. However, a significant number of facilities will not be eligible for that program by virtue of not being able to meet all of the EM acceptance criteria. Currently, discussions and information transmittals

Table 9.6

Projected schedule of ORNL facilities to become surplus[a]

	Number of facilities					
		FISCAL YEAR				
	Currently inactive	1992	1993	1994	1995	Total
Research-reactor and related facilities	10	5			9	24
Hot-cell facilities	1	11			2	14
R&D laboratories	16	3	3			22
Support facilities	6	1	1		3	11
Miscellaneous facilities	7	2				9
Total	40	22	4	0	14	80
Cumulative total	40	62	66	66	80	

[a]Facilities not part of the DOE Envrionmental Restoration Decontamination and Decommissioning Program.

Table 9.7
Projected resource requirements for annual surveillance and maintenance (S&M) of ORNL surplus facilities[a]

	S&M cost ($ in thousands)				
		FISCAL YEAR			
	Current	**1992**	**1993**	**1994**	**1995**
Research-reactor and related facilities	753	1301	1301	1301	2116
Hot-cell facilities	100	1275	1275	1275	2605
R&D laboratories	1268	1688	1763	1763	1763
Support facilities	40	45	61	61	71
Miscellaneous facilities	9	9	9	9	9
Total annual S&M cost	**2170**	**4318**	**4409**	**4409**	**6564**

[a]Facilities not part of the DOE Environmental Restoration Decontamination and Decommissioning Program.

are taking place with ER to ensure awareness of this large and diverse inventory of surplus facilities. The goal of this effort is to have a comprehensive program at ORNL to manage surplus facilities through EM and ER funds and to limit future impacts to the R&D mission through burdens to division and Laboratory overhead.

Facilities Resource Requirements

Table 9.2 lists ORNL's currently proposed major construction projects along with the estimated funding requirements to implement these plans.

Computing and Networking Requirements

The computing strategy for ORNL is laid out in a strategic plan that is updated yearly.[1] The overall objective, as endorsed by Laboratory management, is to "provide a computing environment that is among the best in the country." Increasingly, the missions of ORNL are dependent on computing resources and computing expertise. Consequently, the plan is designed both to remedy shortcomings and to step out aggressively to provide ORNL researchers with a competitive advantage in computing resources.

[1]*Office of Laboratory Computing, Strategic Plan for Computing at Oak Ridge National Laboratory, FY 1991–1995*, ORNL/PPA/INT-90/3, August 1990; *Office of Laboratory Computing, Strategic Plan for Computing at Oak Ridge National Laboratory, FY 1992–1996*, ORNL/PPA/INT-91/2, to be published.

The Center for Computational Science described in the "Major Initiatives" section is the centerpiece of the ORNL strategy for scientific computing. However, there are other elements to the strategy. ORNL and the Energy Systems C&TD are exploring approaches to giving ORNL greater management control over the production computing resources on which ORNL depends. Many of these resources are operated by C&TD.

Despite the existing fiber-distributed data interface (FDDI) fiber-optic network joining six ORNL buildings, an extensive Ethernet network, and T1 (1.5 Mbps) access to wide area research networks, networking speed is still an impediment to distributed computing for many users. Consequently, network improvement will be a high priority until distributed computing is no longer limited to a network.

In terms of computing resources, ORNL will maintain a flexible stance—not tied to a particular vendor but built on open system and open network principles and conforming to widely accepted industry standards. To achieve this, any growth in capacity will be in open systems platforms rather than proprietary environments.

10 Resource Projections

10 • Resource Projections

Oak Ridge National Laboratory's resource projections are presented in the following tables:

- Table 10.1, Laboratory funding summary,
- Table 10.2, Laboratory personnel summary,
- Table 10.3, Funding by assistant secretarial level office,
- Table 10.4, Personnel by assistant secretarial level office,
- Table 10.5, Resources by program,
- Table 10.6, Subcontracting and procurement, and
- Table 10.7, Small and disadvantaged business procurement.

Tables 10.1, 10.3, 10.5, and 10.7 report resource projections for funding in millions of dollars budget authorization (BA). These resource projections reflect new BA funding requested in the FY 1994 budget submission document adjusted to incorporate any interim guidance. New BA requests are calculated by adding estimates of outstanding commitments and prefinancing to the total cost and then subtracting the prior-year uncosted budget. The inflation escalation factor in BA funding dollars for both FY 1993 and FY 1994 is 4.0%. BA funding dollars for FY 1995 through FY 1998 are reported in constant FY 1994 dollars.

Subcontracting and procurement funding is reported in Table 10.6 as total dollars obligated funds for each fiscal year.

Personnel statistics are reported as the number of full-time equivalent (FTE) employees in Tables 10.2 and 10.4.

Table 10.1
Laboratory funding summary
($ in millions—BA)[a]

	FISCAL YEAR							
	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
DOE effort	385.6	483.4[b]	714.3[b]	789.2[b]	788.1	796.2	804.3	812.3
Work for Others[c]	100.0	70.8	87.9	100.7	100.8	100.8	100.8	100.8
Total operating	**485.6**	**554.2**	**802.2**	**889.9**	**888.9**	**897.0**	**905.1**	**913.1**
Capital equipment	20.4	28.0	31.5	35.4	33.7	34.1	34.5	34.6
Construction	21.4	11.1	0.0	0.0	0.0	0.0	0.0	0.0
General-purpose facilities funded/budgeted	6.5	2.8	14.9	23.3	21.3	26.6	52.0	66.0
General plant projects	6.1	7.7	7.0	11.4	11.4	11.4	11.4	11.4
General-purpose equipment	3.0	3.4	18.7	17.9	17.9	17.9	17.9	17.9
Total Laboratory	**543.0**	**607.2**	**874.3**	**976.3**	**974.9**	**987.0**	**1020.9**	**1043.0**
Proposed construction			10.1	70.6	134.6	208.5	371.5	608.2
Total projected funding	**543.0**	**607.2**	**884.4**	**1046.9**	**1109.5**	**1195.5**	**1392.4**	**1651.2**

[a]Inflation escalation factor for FY 1993 and FY 1994 is 4.0%. Figures for FY 1995 through FY 1998 are in constant FY 1994 dollars. BA in table is new BA requirement as requested in the FY 1994 budget submission adjusted to incorporate any interim guidance. New BA is calculated by adding estimates of outstanding commitments and prefinancing to the total cost and then subtracting the prior-year uncosted budget.

[b]Includes several field-work proposals proposed in 1994 budget submission to cover Occupational Safety and Health Administration and other safety and health compliance needs.

[c]Includes Nuclear Regulatory Commission. In addition, there are a few Work for Others (WFO) projects that have ORNL staff as principal investigators, but part of the funding is reported through the Y-12 and K-25 financial plans.

Table 10.2
Laboratory personnel summary
[Full-time equivalents (FTEs)]

	FISCAL YEAR							
	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Direct DOE effort	1361	1643	2088	2153	2168	2168	2169	2170
Work for Others[a]	303	346	325	350	350	350	350	350
Total technical direct	**1664**	**1989**	**2413**	**2503**	**2518**	**2518**	**2519**	**2520**
Other direct	158	280	411	392	392	392	392	392
Total direct personnel	**1822**	**2270**	**2824**	**2895**	**2910**	**2910**	**2911**	**2912**
Indirect personnel	2650	2650	2650	2700	2700	2700	2700	2700
Total Laboratory	**4472**	**4920**	**5474**	**5595**	**5610**	**5610**	**5611**	**5612**

[a]Includes Nuclear Regulatory Commission.

Table 10.3
Funding by assistant secretarial level office
($ in millions—BA)[a]

	FISCAL YEAR							
	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Office of Energy Research[b,c]								
Operating expense	158.0	205.2	290.2	330.7	330.8	330.9	331.0	331.0
Capital equipment[c]	10.6	17.2	36.0	37.0	38.7	37.0	37.0	37.0
Construction[c]	9.7	5.1	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction[d]			16.0	97.3	159.3	238.5	426.9	677.6
Total[c]	**178.3**	**227.5**	**342.2**	**465.0**	**528.8**	**606.4**	**794.9**	**1045.6**
Assistant Secretary for Nuclear Energy								
Operating expense	38.8	34.9	67.7	65.8	65.8	65.8	65.8	65.8
Capital equipment	0.5	0.4	1.1	2.1	2.1	2.1	2.1	2.1
Total	**39.3**	**35.3**	**68.8**	**67.9**	**67.9**	**67.9**	**67.9**	**67.9**
Office of New Production Reactors[e]								
Operating expense	(0.8)	0.5	0.5	0.3	0.3	0.3	0.3	0.3
Capital equipment	2.2	1.1	0.5	0.3	0.3	0.3	0.3	0.3
Construction	8.7	8.8	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction[d]			7.9	8.0	8.0	8.0	8.0	8.0
Total	**10.1**	**10.4**	**8.9**	**8.6**	**8.6**	**8.6**	**8.6**	**8.6**
Office of Civilian Radioactive Waste Management								
Operating expense	8.6	0.5	1.6	1.2	1.2	1.2	1.2	1.2
Assistant Secretary for Defense Programs[c]								
Operating expense	7.1	10.9	12.4	11.5	11.5	11.5	11.5	11.5
Capital equipment	0.4	0.4	1.8	2.0	2.1	2.2	2.3	2.4
Proposed construction[d]			1.1	0.0	0.0	0.0	0.0	0.0
Total[c]	**7.5**	**11.3**	**15.3**	**13.5**	**13.6**	**13.7**	**13.8**	**13.9**
Assistant Secretary for Conservation and Renewable Energy								
Operating expense	60.5	61.8	72.4	86.2	85.0	93.0	101.0	109.9
Capital equipment	2.7	3.7	4.0	4.8	4.6	4.9	5.2	5.2
Total	**63.2**	**65.5**	**76.4**	**91.0**	**89.6**	**97.9**	**106.2**	**114.2**

Table 10.3
(continued)

	FISCAL YEAR							
	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Assistant Secretary for Fossil Energy								
Operating expense	6.8	6.9	6.9	11.7	11.7	11.7	11.7	11.7
Capital equipment	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total	**6.8**	**7.0**	**7.0**	**11.8**	**11.8**	**11.8**	**11.8**	**11.8**
Assistant Secretary for Environment, Safety, and Health								
Operating expense	7.8	7.2	7.5	7.6	7.6	7.6	7.6	7.6
Capital equipment	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Total	**7.8**	**7.2**	**7.6**	**7.7**	**7.7**	**7.7**	**7.7**	**7.7**
Office of Environmental Restoration and Waste Management[b]								
Operating expense	13.8	12.5	0.0	0.0	0.0	0.0	0.0	0.0
Capital equipment	4.2	5.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	6.1	7.7	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction[d]			7.0	0.0	0.0	0.0	0.0	0.0
Total	**24.1**	**25.2**	**7.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Energy Information Administration								
Operating expense	0.9	0.8	0.8	0.9	0.9	0.9	0.9	0.9
Office of Administration and Human Resource Management								
Operating expense	0.4	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Construction[c]	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**1.4**	**0.1**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**
Office of Policy, Planning, and Analysis								
Operating expense	2.1	2.5	2.4	2.7	2.7	2.7	2.7	2.7
Federal Energy Regulatory Commission								
Operating expense	0.6	2.1	2.4	1.6	1.6	1.6	1.6	1.6
Assistant Secretary for International Affairs and Energy Emergencies								
Operating expense	0.1	0.1	0.3	0.3	0.3	0.3	0.3	0.3

Table 10.3
(continued)

	FISCAL YEAR							
	1991	1992	1993	1994	1995	1996	1997	1998
Office of Nuclear Safety								
Operating expense	0.1	0.2	0.3	0.3	0.3	0.3	0.3	0.3
DOE Funding from Energy Systems Central Organizations								
Operating expense	58.2	116.2	219.0	238.9	238.9	238.9	238.9	238.9
Capital equipment[c]	0.0	0.2	0.3	0.0	0.0	0.0	0.0	0.0
Construction	8.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**66.7**	**116.4**	**219.3**	**238.9**	**238.9**	**238.9**	**238.9**	**238.9**
Subtotal DOE Programs								
Operating expense	363.0	462.4	684.6	759.9	758.8	766.9	775.0	783.0
Capital equipment	20.6	28.1	43.9	46.4	48.0	46.7	47.1	47.2
Construction	34.0	21.6	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction[d]			32.0	105.3	167.3	246.5	434.9	685.6
Total[c]	**417.6**	**512.1**	**760.5**	**911.6**	**974.1**	**1060.1**	**1257.0**	**1515.8**
DOE Contractors and Operations Office								
Operating expense	22.6	21.0	29.7	29.3	29.3	29.3	29.3	29.3
Capital equipment	0.0	0.2	3.0	2.0	2.0	2.0	2.0	2.0
Total	**22.6**	**21.2**	**32.7**	**31.3**	**31.3**	**31.3**	**31.3**	**31.3**
Total DOE Programs[b,c]								
Operating expense	385.6	483.4	714.3	789.2	788.1	796.2	804.3	812.3
Capital equipment[c]	20.6	28.3	46.9	48.4	50.0	48.7	49.1	49.2
Construction[c]	34.0	21.6	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction[d]			32.0	105.3	167.3	246.5	434.9	685.6
Total DOE programs[c]	**440.2**	**533.3**	**793.2**	**942.9**	**1005.4**	**1091.4**	**1288.3**	**1547.1**
Nuclear Regulatory Commission								
Operating expense	18.3	20.4	19.7	19.7	19.7	19.7	19.7	19.7
Capital equipment	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Total	**18.5**	**20.7**	**20.0**	**20.0**	**20.0**	**20.0**	**20.0**	**20.0**

Table 10.3
(continued)

	FISCAL YEAR							
	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Department of Defense								
Operating expense	51.2	32.2	40.8	48.3	48.3	48.3	48.3	48.3
Capital equipment	2.1	2.1	2.2	2.2	2.2	2.2	2.2	2.2
Total	**53.3**	**34.3**	**43.0**	**50.5**	**50.5**	**50.5**	**50.5**	**50.5**
National Aeronautics and Space Administration								
Operating expense	5.5	5.9	5.0	13.0	13.0	13.0	13.0	13.0
Department of Health and Human Services								
Operating expense	5.1	4.8	6.6	6.7	6.7	6.7	6.7	6.7
Captal equipment	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total	**5.2**	**4.9**	**6.7**	**6.8**	**6.8**	**6.8**	**6.8**	**6.8**
Environmental Protection Agency								
Operating expense	2.4	1.2	2.9	3.1	3.1	3.1	3.1	3.1
National Science Foundation								
Operating expense	1.1	0.8	0.2	0.2	0.2	0.2	0.2	0.2
Federal Emergency Management Agency								
Operating expense	2.5	3.5	4.2	3.4	3.4	3.4	3.4	3.4
Agency for International Development								
Operating expense	0.8	0.7	0.8	0.8	0.8	0.8	0.8	0.8
Other Federal Agencies								
Operating expense	4.6	(2.2)[f]	3.2	2.6	2.6	2.6	2.6	2.6
Capital equipment	0.4	0.6	0.7	0.7	0.7	0.7	0.7	0.7
Total	**5.0**	**(1.6)[f]**	**3.9**	**3.3**	**3.3**	**3.3**	**3.3**	**3.3**
Electric Power Research Institute								
Operating expense	2.7	1.1	2.0	1.8	1.8	1.8	1.8	1.8

Table 10.3
(continued)

	FISCAL YEAR							
	1991	1992	1993	1994	1995	1996	1997	1998
Other Nonfederal Agencies								
Operating expense	5.8	2.4	2.5	1.1	1.2	1.2	1.2	1.2
Total Work for Others								
Operating expense	100.0	70.8	87.9	100.7	100.8	100.8	100.8	100.8
Capital equipment	2.8	3.1	3.3	3.3	3.3	3.3	3.3	3.3
Total	**102.8**	**73.9**	**91.2**	**104.0**	**104.1**	**104.1**	**104.1**	**104.1**
Total Laboratory[b,c]								
Operating expense	485.6	554.2	802.2	889.9	888.9	897.0	905.1	913.1
Capital equipment[g]	23.4	31.4	50.2	51.7	53.3	52.0	52.4	52.5
Construction[h]	34.0	21.6	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction[d]			32.0	105.3	167.3	246.5	434.9	685.6
Total	**543.0**	**607.2**	**852.4**	**1046.9**	**1109.5**	**1195.5**	**1392.4**	**1651.2**

[a]Inflation escalation factor for FY 1993 and FY 1994 is 4.0%. Figures for FY 1995 through FY 1998 are in constant FY 1994 dollars. BA in table is new BA requirement as requested in the FY 1994 budget submission adjusted to incorporate any interim guidance. New BA is calculated by adding estimates of outstanding commitments and prefinancing to the total cost and then subtracting the prior-year uncosted budget.

[b]FY 1994 data include several field work proposals included in the 1994 budget submission to fund Occupational Safety and Health Administration and other safety and health compliance needs.

[c]Includes some general plant projects and/or general-purpose equipment funding.

[d]Proposed construction lists budgeted amounts for FY 1993–1998 and includes multipurpose general-purpose facilities and general plant projects.

[e]Does not include DOE new production reactor (DOE-NP) funding via transfers from other DOE laboratories.

[f]Parentheses contain negative amounts, indicating a budgetary deobligation.

[g]Capital equipment includes general-purpose equipment.

[h]Construction lists funded amounts for FY 1991 and 1992 and includes multiprogram general-purpose facilities and general plant projects.

Table 10.4

Personnel by assistant secretarial level office

[Full-time equivalents (FTEs)]

	FISCAL YEAR							
	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Office of Energy Research								
Technical personnel	662.2	751.5	1035.2	1061.7	1062.1	1062.4	1062.9	1063.3
Other direct personnel	72.3	108.9	149.4	140.2	140.2	140.2	140.3	140.3
Total direct personnel	**734.5**	**860.4**	**1184.6**	**1201.9**	**1202.3**	**1202.6**	**1203.2**	**1203.6**
Assistant Secretary for Nuclear Energy								
Technical personnel	162.1	148.2	262.9	251.6	251.6	251.6	251.6	251.6
Other direct personnel	19.1	44.2	73.5	73.1	73.1	73.1	73.1	73.1
Total direct personnel	**181.2**	**192.4**	**336.4**	**324.7**	**324.7**	**324.7**	**324.7**	**324.7**
Office of New Production Reactors								
Technical personnel	2.0	2.5	2.6	1.5	1.5	1.5	1.5	1.5
Other direct personnel	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**2.2**	**2.5**	**2.6**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Office of Civilian Radioactive Waste Management								
Technical personnel	10.7	8.7	5.1	3.9	18.0	18.2	18.4	18.6
Other direct personnel	3.7	3.4	2.8	1.6	1.6	1.6	1.6	1.6
Total direct personnel	**14.4**	**12.1**	**7.9**	**5.5**	**19.6**	**19.8**	**20.0**	**20.2**
Assistant Secretary for Defense Programs								
Technical personnel	40.6	58.2	68.3	61.0	61.0	61.0	61.0	61.0
Other direct personnel	0.5	3.5	2.8	3.8	3.8	3.8	3.8	3.8
Total direct personnel	**41.1**	**61.7**	**71.1**	**64.8**	**64.8**	**64.8**	**64.8**	**64.8**
Assistant Secretary for Conservation and Renewable Energy								
Technical personnel	127.9	171.1	188.9	205.0	205.0	205.0	205.0	205.0
Other direct personnel	3.4	2.3	1.8	2.0	2.0	2.0	2.0	2.0
Total direct personnel	**131.3**	**173.4**	**190.7**	**207.0**	**207.0**	**207.0**	**207.0**	**207.0**

Table 10.4
(continued)

	FISCAL YEAR							
	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Assistant Secretary for Fossil Energy								
Technical personnel	17.1	23.9	24.0	27.9	27.9	27.9	27.9	27.9
Other direct personnel	0.3	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Total direct personnel	**17.4**	**23.9**	**24.1**	**28.0**	**28.0**	**28.0**	**28.0**	**28.0**
Assistant Secretary for Environment, Safety, and Health								
Technical personnel	25.1	28.8	26.3	23.7	23.7	23.7	23.7	23.7
Other direct personnel	0.7	0.7	0.8	0.7	0.7	0.7	0.7	0.7
Total direct personnel	**25.8**	**29.5**	**27.1**	**24.4**	**24.4**	**24.4**	**24.4**	**24.4**
Office of Environmental Restoration and Waste Management								
Technical personnel	27.2	29.3	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	1.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**28.2**	**30.8**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Energy Information Administration								
Technical personnel	2.4	2.8	2.8	2.7	2.7	2.7	2.7	2.7
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**2.4**	**2.8**	**2.8**	**2.7**	**2.7**	**2.7**	**2.7**	**2.7**
Office of Administration and Human Resource Management								
Technical personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	0.2	1.3	0.3	0.3	0.3	0.3	0.3	0.3
Total direct personnel	**0.2**	**1.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**
Office of Policy, Planning, and Analysis								
Technical personnel	6.8	7.0	8.6	8.2	8.2	8.2	8.2	8.2
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**6.8**	**7.0**	**8.6**	**8.2**	**8.2**	**8.2**	**8.2**	**8.2**

Table 10.4
(continued)

	FISCAL YEAR							
	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Federal Energy Regulatory Commission								
Technical personnel	2.4	9.2	11.6	7.9	7.9	7.9	7.9	7.9
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**2.4**	**9.2**	**11.6**	**7.9**	**7.9**	**7.9**	**7.9**	**7.9**
Assistant Secretary for International Affairs and Energy Emergencies								
Technical personnel	0.2	0.6	1.1	1.2	1.2	1.2	1.2	1.2
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**0.2**	**0.6**	**1.1**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**
Office of Nuclear Safety								
Technical personnel	0.0	1.1	1.7	1.7	1.7	1.7	1.7	1.7
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**0.0**	**1.1**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**
DOE Funding from Energy Systems Central Organizations								
Technical personnel	274.6	310.5	359.6	412.4	412.4	412.4	412.4	412.4
Other direct personnel	24.7	58.4	117.8	125.3	125.3	125.3	125.3	125.3
Total direct personnel	**299.3**	**368.9**	**477.4**	**537.7**	**537.7**	**537.7**	**537.7**	**537.7**
Subtotal DOE Programs								
Technical personnel	1361.3	1553.4	1998.7	2070.4	2084.9	2085.4	2086.1	2086.7
Other direct personnel	126.1	224.2	349.3	347.1	347.1	347.1	347.2	347.2
Total direct personnel	**1487.4**	**1777.6**	**2348.0**	**2417.5**	**2432.0**	**2432.5**	**2433.3**	**2433.9**
DOE Contractors and Operations Office								
Technical personnel		89.4	89.2	82.6	82.6	82.6	82.6	82.6
Other direct personnel		11.8	14.4	14.3	14.3	14.3	14.3	14.3
Total direct personnel	**0.0**	**101.2**	**103.6**	**96.9**	**96.9**	**96.9**	**96.9**	**96.9**

Table 10.4
(continued)

	FISCAL YEAR							
	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Total DOE Programs								
Technical personnel	1361.3	1642.8	2087.9	2153.0	2167.5	2168.0	2168.7	2169.3
Other direct personnel	126.1	236.0	363.7	361.4	361.4	361.4	361.5	361.5
Total direct personnel	**1487.4**	**1878.8**	**2451.6**	**2514.4**	**2528.9**	**2529.4**	**2530.2**	**2530.8**
Work for Others								
Nuclear Regulatory Commission								
Technical personnel	56.1	68.7	60.7	59.5	59.5	59.5	59.5	59.5
Other direct personnel	14.9	10.3	9.5	9.1	9.1	9.1	9.1	9.1
Total direct personnel	**71.0**	**79.0**	**70.2**	**68.6**	**68.6**	**68.6**	**68.6**	**68.6**
Department of Defense								
Technical personnel	139.3	151.3	137.7	165.4	165.4	165.4	165.4	165.4
Other direct personnel	11.2	20.3	13.2	12.1	12.1	12.1	12.1	12.1
Total direct personnel	**150.5**	**171.6**	**150.9**	**177.5**	**177.5**	**177.5**	**177.5**	**177.5**
National Aeronautics and Space Administration								
Technical personnel	13.7	18.5	19.1	34.0	34.0	34.0	34.0	34.0
Other direct personnel	0.3	8.5	20.0	5.2	5.2	5.2	5.2	5.2
Total direct personnel	**14.0**	**27.0**	**39.1**	**39.2**	**39.2**	**39.2**	**39.2**	**39.2**
Department of Health and Human Services								
Technical personnel	21.2	29.6	27.5	26.3	26.3	26.3	26.3	26.3
Other direct personnel	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Total direct personnel	**21.5**	**29.8**	**27.7**	**26.5**	**26.5**	**26.5**	**26.5**	**26.5**
Environmental Protection Agency								
Technical personnel	12.9	14.0	16.5	16.4	16.4	16.4	16.4	16.4
Other direct personnel	0.8	0.4	0.6	0.6	0.6	0.6	0.6	0.6
Total direct personnel	**13.7**	**14.4**	**17.1**	**17.0**	**17.0**	**17.0**	**17.0**	**17.0**

Table 10.4
(continued)

	FISCAL YEAR							
	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
National Science Foundation								
Technical personnel	1.5	1.3	1.4	0.9	0.9	0.9	0.9	0.9
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**1.5**	**1.3**	**1.4**	**0.9**	**0.9**	**0.9**	**0.9**	**0.9**
Federal Emergency Management Agency								
Technical personnel	6.1	13.5	16.0	18.3	18.3	18.3	18.3	18.3
Other direct personnel	0.8	1.0	0.9	0.9	0.9	0.9	0.9	0.9
Total direct personnel	**6.9**	**14.5**	**16.9**	**19.2**	**19.2**	**19.2**	**19.2**	**19.2**
Agency for International Development								
Technical personnel	2.8	5.2	3.8	3.6	3.6	3.6	3.6	3.6
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**2.8**	**5.2**	**3.8**	**3.6**	**3.6**	**3.6**	**3.6**	**3.6**
Other Federal Agencies								
Technical personnel	26.2	18.0	21.5	12.3	12.3	12.3	12.3	12.3
Other direct personnel	1.2	1.8	2.2	2.2	2.2	2.2	2.2	2.2
Total direct personnel	**27.4**	**19.8**	**23.7**	**14.5**	**14.5**	**14.5**	**14.5**	**14.5**
Electric Power Research Institute								
Technical personnel	9.2	9.9	8.1	6.1	6.1	6.1	6.1	6.1
Other direct personnel	0.8	1.3	0.4	0.3	0.3	0.3	0.3	0.3
Total direct personnel	**10.0**	**11.2**	**8.5**	**6.4**	**6.4**	**6.4**	**6.4**	**6.4**
Other Nonfederal Agencies								
Technical personnel	14.0	16.4	12.6	7.5	7.5	7.5	7.5	7.5
Other direct personnel	1.4	0.6	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**15.4**	**17.0**	**12.6**	**7.5**	**7.5**	**7.5**	**7.5**	**7.5**

Table 10.4
(continued)

	FISCAL YEAR							
	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Total Work for Others								
Technical personnel	303.0	346.4	324.9	350.3	350.3	350.3	350.3	350.3
Other direct personnel	31.7	44.4	47.0	30.6	30.6	30.6	30.6	30.6
Total direct personnel	**334.7**	**390.8**	**371.9**	**380.9**	**380.9**	**380.9**	**380.9**	**380.9**
Total Laboratory Personnel								
Technical personnel[a]	1664.3	1989.2	2412.8	2503.3	2517.8	2518.3	2519.0	2519.6
Other direct personnel	157.8	280.4	410.7	392.0	392.0	392.0	392.1	392.1
Total Laboratory direct personnel	**1822.1**	**2269.6**	**2823.5**	**2895.3**	**2909.8**	**2910.3**	**2911.1**	**2911.7**
Total Laboratory indirect personnel	**2650**	**2650**	**2650**	**2700**	**2700**	**2700**	**2700**	**2700**
Total Laboratory personnel	**4472**	**4920**	**5474**	**5595**	**5610**	**5610**	**5611**	**5612**

[a]Includes several field-work proposals included in FY 1994 budget submission to fund Occupational Safety and Health Administration and other safety and health compliance needs.

Table 10.5

Resources by major program

[$ in millions—BA;[a] personnel in full-time equivalents (FTEs)]

	FISCAL YEAR							
	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
			Office of Energy Research					
AT—Magnetic Fusion								
Operating expense	25.0	27.7	38.2	48.3	48.3	48.3	48.3	48.3
Capital equipment	1.2	2.6	2.9	2.1	2.1	2.1	2.1	2.1
Construction	0.2	(2.8)[b]	0.0	0.0	0.0	0.0	0.0	0.0
Total program funding	**26.4**	**27.5**	**41.1**	**50.4**	**50.4**	**50.4**	**50.4**	**50.4**
Technical personnel	82.4	83.7	95.0	124.3	124.3	124.3	124.3	124.3
Other direct personnel	38.0	35.5	50.6	61.2	61.2	61.2	61.2	61.2
Total direct personnel	**120.4**	**119.2**	**145.6**	**185.5**	**185.5**	**185.5**	**185.5**	**185.5**
KA—High Energy Physics								
Operating expense	0.4	0.5	1.3	1.6	1.6	1.6	1.6	1.6
Technical personnel	2.0	2.1	5.3	6.3	6.3	6.3	6.3	6.3
Other direct personnel	0.2	0.0	0.4	0.4	0.4	0.4	0.4	0.4
Total direct personnel	**2.2**	**2.1**	**5.7**	**6.7**	**6.7**	**6.7**	**6.7**	**6.7**
KB—Nuclear Physics								
Operating expense	12.7	14.2	12.0	13.1	13.1	13.1	13.1	13.1
Capital equipment	1.0	0.9	0.9	1.1	1.1	1.1	1.1	1.1
Construction	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Total program funding	**13.8**	**15.3**	**12.9**	**14.2**	**14.2**	**14.2**	**14.2**	**14.2**
Technical personnel	64.1	60.9	53.5	57.0	57.0	57.0	57.0	57.0
Other direct personnel	0.8	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Total direct personnel	**64.9**	**62.4**	**55.0**	**58.5**	**58.5**	**58.5**	**58.5**	**58.5**
KC—Basic Energy Sciences								
Operating expense	89.7	115.9	129.7	130.5	130.5	130.5	130.5	130.5
Capital equipment	6.7	7.8	11.0	12.0	13.7	12.0	12.0	12.0
Construction	2.8	4.9	0.0	0.0	0.0	0.0	0.0	0.0
Total program funding	**99.2**	**128.6**	**140.7**	**142.5**	**144.2**	**142.5**	**142.5**	**142.5**

Table 10.5
(continued)

	FISCAL YEAR							
	1991	1992	1993	1994	1995	1996	1997	1998
Proposed construction			1.1	46.6	88.6	168.5	359.5	600.2
Technical personnel	398.1	429.1	489.1	468.8	468.8	468.8	468.8	468.8
Other direct personnel	32.2	58.3	58.8	12.2	12.2	12.2	12.2	12.2
Total direct personnel	**430.3**	**487.4**	**547.9**	**481.0**	**481.0**	**481.0**	**481.0**	**481.0**
KD—Energy Research Analyses								
Operating expense	0.6	1.1	1.5	1.5	1.5	1.5	1.5	1.5
Technical personnel	3.2	3.1	2.8	2.2	2.2	2.2	2.2	2.2
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**3.2**	**3.1**	**2.8**	**2.2**	**2.2**	**2.2**	**2.2**	**2.2**
KG—Multiprogram Energy Laboratory—Facility Support								
Operating expense	0.0	0.0	0.0	2.2	2.2	2.2	2.2	2.2
Capital equipment		0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction[c]	6.5	2.8						
Total program funding	**6.5**	**2.8**	**0.0**	**2.2**	**2.2**	**2.2**	**2.2**	**2.2**
Proposed construction			14.9	23.3	21.3	26.6	52.0	66.0
Technical personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	0.0	0.0	0.0	6.0	6.0	6.0	6.0	6.0
Total direct personnel	**0.0**	**0.0**	**0.0**	**6.0**	**6.0**	**6.0**	**6.0**	**6.0**
KP—Biological and Environmental Research								
Operating expense	27.3	31.3	38.1	40.7	40.7	40.7	40.7	40.7
Capital equipment	1.4	2.4	2.5	3.9	3.9	3.9	3.9	3.9
Total program funding	**28.7**	**33.7**	**40.6**	**44.6**	**44.6**	**44.6**	**44.6**	**44.6**
Proposed construction		0.0	0.0	16.0	38.0	32.0	4.0	0.0
Technical personnel	108.3	113.7	139.0	140.6	140.6	140.6	140.6	140.6
Other direct personnel	1.1	4.8	6.5	4.6	4.6	4.6	4.6	4.6
Total direct personnel	**109.4**	**118.5**	**145.5**	**145.2**	**145.2**	**145.2**	**145.2**	**145.2**

Table 10.5
(continued)

	FISCAL YEAR							
	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
KS—Superconducting Super Collider								
Operating expense	0.8	0.1	0.5	0.5	0.5	0.6	0.6	0.6
Capital equipment	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total program funding	**1.1**	**0.1**	**0.5**	**0.5**	**0.5**	**0.6**	**0.6**	**0.6**
Technical personnel	1.8	1.0	2.2	2.3	2.4	2.5	2.7	2.8
Other direct personnel	0.0	3.1	0.4	0.4	0.4	0.4	0.5	0.5
Total direct personnel	**1.8**	**4.1**	**2.6**	**2.7**	**2.8**	**2.9**	**3.2**	**3.3**
KT—University and Science Education								
Operating expense	1.5	1.3	1.6	1.7	1.7	1.7	1.7	1.7
Technical personnel	2.3	4.1	4.2	4.2	4.2	4.2	4.2	4.2
Other direct personnel	0.0	0.1	0.3	0.3	0.3	0.3	0.3	0.3
Total direct personnel	**2.3**	**4.2**	**4.5**	**4.5**	**4.5**	**4.5**	**4.5**	**4.5**
KU—Technology Transfer								
Operating expense	0.0	2.0	1.8	1.0	1.1	1.1	1.2	1.2
Capital equipment	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total program funding	**0.0**	**2.1**	**1.8**	**1.0**	**1.1**	**1.1**	**1.2**	**1.2**
Technical personnel	0.0	8.7	8.9	5.2	5.5	5.7	6.0	6.3
Other direct personnel	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**0.0**	**8.8**	**9.0**	**5.2**	**5.5**	**5.7**	**6.0**	**6.3**
KV—University and Science Education								
Operating expense	0.0	0.3	0.4	0.4	0.4	0.4	0.4	0.4
Technical personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

Table 10.5
(continued)

	FISCAL YEAR							
	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Landlord								
Operating expense	0.0	10.8[d]	65.1[d]	89.2[d]	89.2	89.2	89.2	89.2
General-purpose equipment	0.0	3.4	18.7	17.9	17.9	17.9	17.9	17.9
General plant projects construction	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total program funding	**0.1**	**14.2**	**83.8**	**107.1**	**107.1**	**107.1**	**107.1**	**107.1**
Proposed general plant projects construction	0.0	0.0	0.0	11.4	11.4	11.4	11.4	11.4
Technical personnel	0.0	45.1	235.2	250.8	250.8	250.8	250.8	250.8
Other direct personnel	0.0	5.5	30.8	53.6	53.6	53.6	63.6	53.6
Total direct personnel	**0.0**	**50.6**	**266.0**	**304.4**	**304.4**	**304.4**	**304.4**	**304.4**
Total Office of Energy Research								
Operating expense	158.0	205.2[d]	290.2[d]	330.7[d]	330.8	330.9	331.0	331.0
Capital equipment	10.6	17.2	36.0	37.0	38.7	37.0	37.0	37.0
Construction	9.7	5.1	0.0	0.0	0.0	0.0	0.0	0.0
Total program funding	**178.3**	**227.5**[d]	**326.2**[d]	**367.7**[d]	**369.5**	**367.9**	**368.0**	**368.0**
Proposed construction	0.0	0.0	16.0	97.3	159.3	238.5	426.9	677.6
Technical personnel	662.2	751.5	1035.2	1061.7	1062.1	1062.4	1062.9	1063.3
Other direct personnel	72.3	108.9	149.4	140.2	140.2	140.2	140.3	140.3
Total direct personnel	**734.5**	**860.4**	**1184.6**	**1201.9**	**1202.3**	**1202.6**	**1203.2**	**1203.6**
Assistant Secretary for Nuclear Energy								
AF—Nuclear Energy Research and Development								
Operating expense	32.3	24.2	50.0	48.1	48.1	48.1	48.1	48.1
Capital equipment	0.5	0.4	1.1	2.1	2.1	2.1	2.1	2.1
Total program funding	**32.8**	**24.6**	**51.1**	**50.2**	**50.2**	**50.2**	**50.2**	**50.2**
Technical personnel	126.3	106.3	213.2	199.2	199.2	199.2	199.2	199.2
Other direct personnel	13.4	23.4	32.9	34.9	34.9	34.9	34.9	34.9
Total direct personnel	**139.7**	**129.7**	**246.1**	**234.1**	**234.1**	**234.1**	**234.1**	**234.1**

Table 10.5
(continued)

	FISCAL YEAR							
	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
AJ—Naval Reactors								
Operating expense	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Technical personnel	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**
CD—Uranium Enrichment								
Operating expense	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Technical personnel	1.3	2.8	1.4	1.4	1.4	1.4	1.4	1.4
Other direct personnel	0.0	2.2	0.1	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**1.3**	**5.0**	**1.5**	**1.4**	**1.4**	**1.4**	**1.4**	**1.4**
KK—Policy and Management—Nuclear Energy								
Operating expense	2.9	2.2	3.1	3.1	3.1	3.1	3.1	3.1
Technical personnel	2.6	9.7	9.4	12.2	12.2	12.2	12.2	12.2
Other direct personnel	2.7	3.3	3.3	2.4	2.4	2.4	2.4	2.4
Total direct personnel	**5.3**	**13.0**	**12.7**	**14.6**	**14.6**	**14.6**	**14.6**	**14.6**
ST—Isotope Production and Distribution Program[e]								
Operating expense	3.0	7.9	14.0	14.0	14.0	14.0	14.0	14.0
Technical personnel	31.6	29.1	38.6	38.5	38.5	38.5	38.5	38.5
Other direct personnel	3.0	15.3	37.2	35.8	35.8	35.8	35.8	35.8
Total direct personnel	**34.6**	**44.4**	**75.8**	**74.3**	**74.3**	**74.3**	**74.3**	**74.3**
Total Assistant Secretary for Nuclear Energy								
Operating expense	38.8	34.9	67.7	65.8	65.8	65.8	65.8	65.8
Capital equipment	0.5	0.4	1.1	2.1	2.1	2.1	2.1	2.1
Total program funding	**39.3**	**35.3**	**68.8**	**67.9**	**67.9**	**67.9**	**67.9**	**67.9**
Technical personnel	162.1	148.2	262.9	251.6	251.6	251.6	251.6	251.6
Other direct personnel	19.1	44.2	73.5	73.1	73.1	73.1	73.1	73.1
Total direct personnel	**181.2**	**192.4**	**336.4**	**324.7**	**324.7**	**324.7**	**324.7**	**324.7**

Table 10.5
(continued)

	FISCAL YEAR							
	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
			Office of New Production Reactors					
NP—New Production Reactors[f]								
Operating expense	(0.8)[b]	0.5	0.5	0.3	0.3	0.3	0.3	0.3
Capital equipment	2.2	1.1	0.5	0.3	0.3	0.3	0.3	0.3
Construction	8.7	8.8	0.0	0.0	0.0	0.0	0.0	0.0
Total program funding	**10.1**	**10.4**	**1.0**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**
Proposed construction	0.0	0.0	7.9	8.0	8.0	8.0	8.0	8.0
Technical personnel	2.0	2.5	2.6	1.5	1.5	1.5	1.5	1.5
Other direct personnel	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**2.2**	**2.5**	**2.6**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Total Office of New Production Reactors[f]								
Operating expense	(0.8)[b]	0.5	0.5	0.3	0.3	0.3	0.3	0.3
Capital equipment	2.2	1.1	0.5	0.3	0.3	0.3	0.3	0.3
Construction	8.7	8.8	0.0	0.0	0.0	0.0	0.0	0.0
Total program funding	**10.1**	**10.4**	**1.0**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**
Proposed construction	0.0	0.0	7.9	8.0	8.0	8.0	8.0	8.0
Technical personnel	2.0	2.5	2.6	1.5	1.5	1.5	1.5	1.5
Other direct personnel	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**2.2**	**2.5**	**2.6**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
			Office of Civilian Radioactive Waste Management					
DB—Nuclear Waste Fund								
Operating expense	8.6	0.5	1.6	1.2	1.2	1.2	1.2	1.2
Technical personnel	10.7	8.7	5.1	3.9	18.0	18.2	18.4	18.6
Other direct personnel	3.7	3.4	2.8	1.6	1.6	1.6	1.6	1.6
Total direct personnel	**14.4**	**12.1**	**7.9**	**5.5**	**19.6**	**19.8**	**20.0**	**20.2**
Total Office of Civilian Radioactive Waste Management								
Operating expense	8.6	0.5	1.6	1.2	1.2	1.2	1.2	1.2

Table 10.5
(continued)

	FISCAL YEAR							
	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Technical personnel	10.7	8.7	5.1	3.9	18.0	18.2	18.4	18.6
Other direct personnel	3.7	3.4	2.8	1.6	1.6	1.6	1.6	1.6
Total direct personnel	**14.4**	**12.1**	**7.9**	**5.5**	**19.6**	**19.8**	**20.0**	**20.2**
Assistant Secretary for Defense Programs								
GB—Weapons Activities								
Operating expense	0.0	0.2	0.5	0.5	0.5	0.5	0.5	0.5
Technical personnel	1.3	1.2	2.6	2.7	2.7	2.7	2.7	2.7
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**1.3**	**1.2**	**2.6**	**2.7**	**2.7**	**2.7**	**2.7**	**2.7**
GD—Nuclear Safeguards and Security								
Operating expense	0.5	0.3	0.4	0.4	0.4	0.4	0.4	0.4
Capital equipment	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total program funding	**0.6**	**0.4**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**
Technical personnel	2.4	2.0	2.2	2.0	2.0	2.0	2.0	2.0
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**2.4**	**2.0**	**2.2**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**
GE—Materials Production								
Operating expense	6.6	10.4	11.5	10.6	10.6	10.6	10.6	10.6
Capital equipment	0.3	0.3	1.7	1.9	2.0	2.1	2.2	2.3
Total program funding	**6.9**	**10.7**	**13.2**	**12.5**	**12.6**	**12.7**	**12.8**	**12.9**
Proposed construction	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0
Technical personnel	36.9	55.0	63.5	56.3	56.3	56.3	56.3	56.3
Other direct personnel	0.5	3.5	2.8	3.8	3.8	3.8	3.8	3.8
Total direct personnel	**37.4**	**58.5**	**66.3**	**60.1**	**60.1**	**60.1**	**60.1**	**60.1**
Total Assistant Secretary for Defense Programs								
Operating expense	7.1	10.9	12.4	11.5	11.5	11.5	11.5	11.5
Capital equipment	0.4	0.4	1.8	2.0	2.1	2.2	2.3	2.4
Total program funding	**7.5**	**11.3**	**14.2**	**13.5**	**13.6**	**13.7**	**13.8**	**13.9**

Table 10.5
(continued)

	FISCAL YEAR							
	1991	1992	1993	1994	1995	1996	1997	1998
Proposed construction	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0
Technical personnel	40.6	58.2	68.3	61.0	61.0	61.0	61.0	61.0
Other direct personnel	0.5	3.5	2.8	3.8	3.8	3.8	3.8	3.8
Total direct personnel	**41.1**	**61.7**	**71.1**	**64.8**	**64.8**	**64.8**	**64.8**	**64.8**
Assistant Secretary for Conservation and Renewable Energy								
AK—Electric Energy Systems								
Operating expense	7.2	9.8	11.0	12.6	12.6	12.6	12.6	12.6
Capital equipment	0.3	0.3	0.5	0.3	0.3	0.3	0.3	0.3
Total program funding	**7.5**	**10.1**	**11.5**	**12.9**	**12.9**	**12.9**	**12.9**	**12.9**
Technical personnel	17.7	24.7	28.4	31.2	31.2	31.2	31.2	31.2
Other direct personnel	0.9	0.1	0.4	0.4	0.4	0.4	0.4	0.4
Total direct personnel	**18.6**	**24.8**	**28.8**	**31.6**	**31.6**	**31.6**	**31.6**	**31.6**
AL—Energy Storage Systems								
Operating expense	1.2	0.8	0.2	0.0	0.0	0.0	0.0	0.0
Technical personnel	1.6	1.8	0.7	0.0	0.0	0.0	0.0	0.0
Other direct personnel	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**1.6**	**2.5**	**0.7**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
AM—Geothermal Energy								
Operating expense	4.7	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Technical personnel	1.7	3.7	4.1	2.4	2.4	2.4	2.4	2.4
Other direct personnel	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**1.7**	**3.8**	**4.1**	**2.4**	**2.4**	**2.4**	**2.4**	**2.4**
CE—Hydropower								
Operating expense	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Technical personnel	0.6	0.6	1.0	1.0	1.0	1.0	1.0	1.0
Other direct personnel	0.0	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Total direct personnel	**0.6**	**0.8**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**

Table 10.5
(continued)

	FISCAL YEAR							
	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
EB—Solar Energy								
Operating expense	4.5	4.5	6.0	6.3	6.3	6.3	6.3	6.3
Capital equipment	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total program funding	**4.6**	**4.6**	**6.1**	**6.4**	**6.4**	**6.4**	**6.4**	**6.4**
Technical personnel	10.6	10.7	11.1	10.5	10.5	10.5	10.5	10.5
Other direct personnel	0.2	0.1	0.4	0.5	0.5	0.5	0.5	0.5
Total direct personnel	**10.8**	**10.8**	**11.5**	**11.0**	**11.0**	**11.0**	**11.0**	**11.0**
EC—Buildings Sector								
Operating expense	14.1	11.1	12.6	17.0	17.0	17.0	17.0	17.0
Capital equipment	0.3	0.9	0.7	0.9	0.9	0.9	0.9	0.9
Total program funding	**14.4**	**12.0**	**13.3**	**17.9**	**17.9**	**17.9**	**17.9**	**17.9**
Technical personnel	29.0	35.4	39.4	45.9	45.9	45.9	45.9	45.9
Other direct personnel	1.1	1.0	0.6	0.7	0.7	0.7	0.7	0.7
Total direct personnel	**30.1**	**36.4**	**40.0**	**46.6**	**46.6**	**46.6**	**46.6**	**46.6**
ED—Industrial Sector								
Operating expense	1.9	8.5	11.5	12.5	12.5	12.5	12.5	12.5
Capital equipment	0.0	0.4	0.8	0.9	0.9	0.9	0.9	0.9
Total program funding	**1.9**	**8.9**	**12.3**	**13.4**	**13.4**	**13.4**	**13.4**	**13.4**
Technical personnel	6.8	31.4	37.7	38.9	38.9	38.9	38.9	38.9
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**6.8**	**31.4**	**37.7**	**38.9**	**38.9**	**38.9**	**38.9**	**38.9**
EE—Transportation Sector								
Operating expense	18.9	22.9	28.5	35.2	34.0	42.0	50.0	58.0
Capital equipment	1.7	2.0	1.9	2.6	2.4	2.7	3.0	3.0
Total program funding	**20.6**	**24.9**	**30.4**	**37.8**	**36.4**	**44.7**	**53.0**	**61.0**
Technical personnel	39.9	55.2	59.4	68.8	68.8	68.8	68.8	68.8
Other direct personnel	0.7	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Total direct personnel	**40.6**	**55.3**	**59.6**	**69.0**	**69.0**	**69.0**	**69.0**	**69.0**

Table 10.5
(continued)

	FISCAL YEAR							
	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
EF—Technical and Financial Assistance								
Operating expense	2.0	2.4	1.0	1.0	1.0	1.0	1.0	1.0
Technical personnel	4.5	3.6	3.4	3.1	3.1	3.1	3.1	3.1
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**4.5**	**3.6**	**3.4**	**3.1**	**3.1**	**3.1**	**3.1**	**3.1**
EG—Multi-Sector								
Operating expense	5.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital equipment	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total program funding	**6.1**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Technical personnel	15.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**16.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
EK—Utility Sector								
Operating expense	0.0	1.1	0.9	0.9	0.9	0.9	0.9	0.9
Total personnel	0.0	4.0	3.7	3.2	3.2	3.2	3.2	3.2
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**0.0**	**4.0**	**3.7**	**3.2**	**3.2**	**3.2**	**3.2**	**3.2**
Total Assistant Secretary for Conservation and Renewable Energy								
Operating expense	60.5	61.8	72.4	86.2	85.0	93.0	101.0	109.0
Capital equipment	2.7	3.7	4.0	4.8	4.6	4.9	5.2	5.2
Total program funding	**63.2**	**65.5**	**76.4**	**91.0**	**89.6**	**97.9**	**106.2**	**114.2**
Technical personnel	127.9	171.1	188.9	205.0	205.0	205.0	205.0	205.0
Other direct personnel	3.4	2.3	1.8	2.0	2.0	2.0	2.0	2.0
Total direct personnel	**131.3**	**173.4**	**190.7**	**207.0**	**207.0**	**207.0**	**207.0**	**207.0**

Table 10.5
(continued)

	FISCAL YEAR							
	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
			Assistant Secretary for Fossil Energy					
AA—Coal								
Operating expense	5.9	6.1	5.8	10.5	10.5	10.5	10.5	10.5
Capital equipment	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total program funding	**5.9**	**6.2**	**5.9**	**10.6**	**10.6**	**10.6**	**10.6**	**10.6**
Technical personnel	13.4	17.3	17.4	22.6	22.6	22.6	22.6	22.6
Other direct personnel	0.3	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Total direct personnel	**13.7**	**17.3**	**17.5**	**22.7**	**22.7**	**22.7**	**22.7**	**22.7**
AC—Petroleum								
Operating expense	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Technical personnel	0.0	0.4	0.3	0.3	0.3	0.3	0.3	0.3
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**0.0**	**0.4**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**
AZ—Innovative Clean Coal Technology								
Operating expense	0.5	0.4	0.6	0.7	0.7	0.7	0.7	0.7
Technical personnel	2.2	3.8	4.1	2.9	2.9	2.9	2.9	2.9
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**2.2**	**3.8**	**4.1**	**2.9**	**2.9**	**2.9**	**2.9**	**2.9**
SA—Strategic Petroleum Reserve								
Operating expense	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Technical personnel	1.5	2.4	2.2	2.1	2.1	2.1	2.1	2.1
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**1.5**	**2.4**	**2.2**	**2.1**	**2.1**	**2.1**	**2.1**	**2.1**

Table 10.5
(continued)

	FISCAL YEAR							
	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Total Assistant Secretary for Fossil Energy								
Operating expense	6.8	6.9	6.9	11.7	11.7	11.7	11.7	11.7
Capital equipment	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total program funding	**6.8**	**7.0**	**7.0**	**11.8**	**11.8**	**11.8**	**11.8**	**11.8**
Technical personnel	17.1	23.9	24.0	27.9	27.9	27.9	27.9	27.9
Other direct personnel	0.3	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Total direct personnel	**17.4**	**23.9**	**24.1**	**28.0**	**28.0**	**28.0**	**28.0**	**28.0**
Assistant Secretary for Environment, Safety, and Health								
HA—Environmental Research and Development								
Operating expense	7.5	7.1	7.4	7.5	7.5	7.5	7.5	7.5
Capital equipment	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Total program funding	**7.5**	**7.1**	**7.5**	**7.6**	**7.6**	**7.6**	**7.6**	**7.6**
Technical personnel	24.9	28.4	26.3	23.7	23.7	23.7	23.7	23.7
Other direct personnel	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Total direct personnel	**25.2**	**28.6**	**26.5**	**23.9**	**23.9**	**23.9**	**23.9**	**23.9**
HR—Epidemiologic Activities								
Operating expense	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Technical personnel	0.2	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**0.2**	**0.4**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
HS—Office of Security Evaluations								
Operating expense	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Technical personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	0.4	0.5	0.6	0.5	0.5	0.5	0.5	0.5
Total direct personnel	**0.4**	**0.5**	**0.6**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**

Table 10.5
(continued)

	FISCAL YEAR							
	1991	1992	1993	1994	1995	1996	1997	1998
Total Assistant Secretary for Environment, Safety, and Health								
Operating expense	7.8	7.2	7.5	7.6	7.6	7.6	7.6	7.6
Capital equipment	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Total program funding	**7.8**	**7.2**	**7.6**	**7.7**	**7.7**	**7.7**	**7.7**	**7.7**
Technical personnel	25.1	28.8	26.3	23.7	23.7	23.7	23.7	23.7
Other direct personnel	0.7	0.7	0.8	0.7	0.7	0.7	0.7	0.7
Total direct personnel	**25.8**	**29.5**	**27.1**	**24.4**	**24.4**	**24.4**	**24.4**	**24.4**
National Energy Information System								
TA—National Energy Information System								
Operating expense	0.9	0.8	0.8	0.9	0.9	0.9	0.9	0.9
Technical personnel	2.4	2.8	2.8	2.7	2.7	2.7	2.7	2.7
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**2.4**	**2.8**	**2.8**	**2.7**	**2.7**	**2.7**	**2.7**	**2.7**
Total Energy Information Administration								
Operating expense	0.9	0.8	0.8	0.9	0.9	0.9	0.9	0.9
Technical personnel	2.4	2.8	2.8	2.7	2.7	2.7	2.7	2.7
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**2.4**	**2.8**	**2.8**	**2.7**	**2.7**	**2.7**	**2.7**	**2.7**
Office of Administration and Human Resource Management								
WB—In-House Energy Management								
Operating expense	0.4	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Construction	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total program funding	**1.4**	**0.1**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**
Technical personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	0.2	1.3	0.3	0.3	0.3	0.3	0.3	0.3
Total direct personnel	**0.2**	**1.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**

Table 10.5
(continued)

	FISCAL YEAR							
	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Total Office of Administration and Human Resource Management								
Operating expense	0.4	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Construction	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total program funding	**1.4**	**0.1**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**
Technical personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	0.2	1.3	0.3	0.3	0.3	0.3	0.3	0.3
Total direct personnel	**0.2**	**1.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**
Office of Policy, Planning, and Analysis								
PE—Policy, Planning, and Analysis								
Operating expense	2.1	2.5	2.4	2.7	2.7	2.7	2.7	2.7
Technical personnel	6.8	7.0	8.6	8.2	8.2	8.2	8.2	8.2
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**6.8**	**7.0**	**8.6**	**8.2**	**8.2**	**8.2**	**8.2**	**8.2**
Total Office of Policy, Planning, and Analysis								
Operating expense	2.1	2.5	2.4	2.7	2.7	2.7	2.7	2.7
Technical personnel	6.8	7.0	8.6	8.2	8.2	8.2	8.2	8.2
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**6.8**	**7.0**	**8.6**	**8.2**	**8.2**	**8.2**	**8.2**	**8.2**
Federal Energy Regulatory Commission								
VR—Federal Energy Regulatory Commission								
Operating expense	0.6	2.1	2.4	1.6	1.6	1.6	1.6	1.6
Technical personnel	2.4	9.2	11.6	7.9	7.9	7.9	7.9	7.9
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**2.4**	**9.2**	**11.6**	**7.9**	**7.9**	**7.9**	**7.9**	**7.9**
Total Federal Energy Regulatory Commission								
Operating expense	0.6	2.1	2.4	1.6	1.6	1.6	1.6	1.6

Table 10.5
(continued)

	FISCAL YEAR							
	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Technical personnel	2.4	9.2	11.6	7.9	7.9	7.9	7.9	7.9
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**2.4**	**9.2**	**11.6**	**7.9**	**7.9**	**7.9**	**7.9**	**7.9**
Assistant Secretary for International Affairs and Energy Emergencies								
NB—Emergency Preparedness								
Operating expense	0.1	0.1	0.3	0.3	0.3	0.3	0.3	0.3
Technical personnel	0.2	0.6	1.1	1.2	1.2	1.2	1.2	1.2
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**0.2**	**0.6**	**1.1**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**
Total Assistant Secretary for International Affairs and Energy Emergencies								
Operating expense	0.1	0.1	0.3	0.3	0.3	0.3	0.3	0.3
Technical personnel	0.2	0.6	1.1	1.2	1.2	1.2	1.2	1.2
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**0.2**	**0.6**	**1.1**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**
Office of Nuclear Safety								
NS—Office of Nuclear Safety								
Operating expense	0.1	0.2	0.3	0.3	0.3	0.3	0.3	0.3
Technical personnel	0.0	1.1	1.7	1.7	1.7	1.7	1.7	1.7
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**0.0**	**1.1**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**
Total Office of Nuclear Safety								
Operating expense	0.1	0.2	0.3	0.3	0.3	0.3	0.3	0.3
Technical personnel	0.0	1.1	1.7	1.7	1.7	1.7	1.7	1.7
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**0.0**	**1.1**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**

Table 10.5
(continued)

	FISCAL YEAR							
	1991	1992	1993	1994	1995	1996	1997	1998
	Office of Environmental Restoration and Waste Management							
EW—Environmental Restoration and Waste Management—Defense								
Operating expense	8.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital equipment	0.7	4.5	0.0	0.0	0.0	0.0	0.0	0.0
Total program funding	**9.3**	**4.5**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Technical personnel	24.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**24.8**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
EX—Environmental Restoration and Waste Management—Nondefense								
Operating expense	5.2	12.5	0.0	0.0	0.0	0.0	0.0	0.0
Capital equipment	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0
Total program funding	**5.7**	**13.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Technical personnel	3.0	29.3	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	0.4	1.5	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**3.4**	**30.8**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Landlord								
Operating expense	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General-purpose equipment	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General plant projects construction	6.1	7.7	0.0	0.0	0.0	0.0	0.0	0.0
Total program funding	**9.1**	**7.7**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Proposed construction	0.0	0.0	7.0	0.0	0.0	0.0	0.0	0.0
Technical personnel								
Other direct personnel								
Total direct personnel	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

Table 10.5
(continued)

	FISCAL YEAR							
	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Total Office of Environmental Restoration and Waste Management								
Operating expense	13.8	12.5	0.0	0.0	0.0	0.0	0.0	0.0
Capital equipment	4.2	5.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	6.1	7.7	0.0	0.0	0.0	0.0	0.0	0.0
Total program funding	**24.1**	**25.2**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Proposed construction	0.0	0.0	7.0	0.0	0.0	0.0	0.0	0.0
Technical personnel	27.2	29.3	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	1.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**28.2**	**30.8**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
DOE Funding from Energy Systems Central Organizations								
CD—Uranium Enrichment								
Operating expense	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Technical personnel	5.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**7.6**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
EW—Environmental Restoration and Waste Management—Defense								
Operating expense	43.0	95.7	128.4	117.5	117.5	117.5	117.5	117.5
Capital equipment	0.0	0.2	0.3	0.0	0.0	0.0	0.0	0.0
Total program funding	**43.0**	**95.9**	**128.7**	**117.5**	**117.5**	**117.5**	**117.5**	**117.5**
Technical personnel	167.8	184.2	270.4	284.8	284.8	284.8	284.8	284.8
Other direct personnel	18.3	44.1	90.4	109.7	109.7	109.7	109.7	109.7
Total direct personnel	**186.1**	**228.3**	**360.8**	**394.5**	**394.5**	**394.5**	**394.5**	**394.5**
EX—Environmental Restoration and Waste Management—Nondefense								
Operating expense	12.7	20.5	90.6	121.4	121.4	121.4	121.4	121.4
Construction	8.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total program funding	**21.2**	**20.5**	**90.6**	**121.4**	**121.4**	**121.4**	**121.4**	**121.4**

Table 10.5
(continued)

	FISCAL YEAR							
	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Technical personnel	101.3	126.3	89.2	127.6	127.6	127.6	127.6	127.6
Other direct personnel	4.3	14.3	27.4	15.6	15.6	15.6	15.6	15.6
Total direct personnel	**105.6**	**140.6**	**116.6**	**143.2**	**143.2**	**143.2**	**143.2**	**143.2**
Total DOE Funding from Energy Systems Central Organizations								
Operating expense	58.2	116.2	219.0	238.9	238.9	238.9	238.9	238.9
Capital equipment	0.0	0.2	0.3	0.0	0.0	0.0	0.0	0.0
Construction	8.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total program funding	**66.7**	**116.4**	**219.3**	**238.9**	**238.9**	**238.9**	**238.9**	**238.9**
Technical personnel	274.6	310.5	359.6	412.4	412.4	412.4	412.4	412.4
Other direct personnel	24.7	58.4	117.8	125.3	125.3	125.3	125.3	125.3
Total direct personnel	**299.3**	**368.9**	**477.4**	**537.7**	**537.7**	**537.7**	**537.7**	**537.7**
Subtotal—DOE Programs								
Operating expense	363.0	462.4	684.6	759.9	758.8	766.9	775.0	783.0
Capital equipment	20.6	28.1	43.9	46.4	48.0	46.7	47.1	47.2
Construction	34.0	21.6	0.0	0.0	0.0	0.0	0.0	0.0
Total program funding	**417.6**	**512.1**	**728.5**	**806.3**	**806.8**	**813.6**	**822.1**	**830.2**
Proposed construction	0.0	0.0	32.0	105.3	167.3	246.5	434.9	685.6
Technical personnel	1361.3	1553.4	1998.7	2070.4	2084.9	2085.4	2086.1	2086.7
Other direct personnel	126.1	224.2	349.3	347.1	347.1	347.1	347.2	347.2
Total direct personnel	**1487.4**	**1777.6**	**2348.0**	**2417.5**	**2432.0**	**2432.5**	**2433.3**	**2433.9**
DOE Contractors and Operations Office								
Operating expense	22.6	21.0	29.7	29.3	29.3	29.3	29.3	29.3
Capital equipment	0.0	0.2	3.0	2.0	2.0	2.0	2.0	2.0
Total program funding	**22.6**	**21.2**	**32.7**	**31.3**	**31.3**	**31.3**	**31.3**	**31.3**
Technical personnel		89.4	89.2	82.6	82.6	82.6	82.6	82.6
Other direct personnel		11.8	14.4	14.3	14.3	14.3	14.3	14.3
Total direct personnel	**0.0**	**101.2**	**103.6**	**96.9**	**96.9**	**96.9**	**96.9**	**96.9**

Table 10.5
(continued)

	FISCAL YEAR							
	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Total DOE Programs								
Operating expense	385.6	483.4[d]	714.3[d]	789.2[d]	788.1	796.2	804.3	812.3
Capital equipment	20.6	28.3	46.9	48.4	50.0	48.7	49.1	49.2
Construction	34.0	21.6	0.0	0.0	0.0	0.0	0.0	0.0
Total program funding	**440.2**	**533.3**[d]	**761.2**[d]	**837.6**[d]	**838.1**	**844.9**	**853.4**	**861.5**
Proposed construction	0.0	0.0	32.0	105.3	167.3	246.5	434.9	685.6
Technical personnel	1361.3	1642.8	2087.9	2153.0	2167.5	2168.0	2168.7	2169.3
Other direct personnel	126.1	236.0	363.7	361.4	361.4	361.4	361.5	361.5
Total direct personnel	**1487.4**	**1878.8**	**2451.6**	**2514.4**	**2528.9**	**2529.4**	**2530.2**	**2530.8**
Work for Others								
Federal Organizations								
Nuclear Regulatory Commission								
Operating expense	18.3	20.4	19.7	19.7	19.7	19.7	19.7	19.7
Capital equipment	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Total Program	**18.5**	**20.7**	**20.0**	**20.0**	**20.0**	**20.0**	**20.0**	**20.0**
Technical personnel	56.1	68.7	60.7	59.5	59.5	59.5	59.5	59.5
Other direct personnel	14.9	10.3	9.5	9.1	9.1	9.1	9.1	9.1
Total direct personnel	**71.0**	**79.0**	**70.2**	**68.6**	**68.6**	**68.6**	**68.6**	**68.6**
Department of Defense								
Operating expense	51.2	32.2	40.8	48.3	48.3	48.3	48.3	48.3
Capital equipment	2.1	2.1	2.2	2.2	2.2	2.2	2.2	2.2
Total program funding	**53.3**	**34.3**	**43.0**	**50.5**	**50.5**	**50.5**	**50.5**	**50.5**
Technical personnel	139.3	151.3	137.7	165.4	165.4	165.4	165.4	165.4
Other direct personnel	11.2	20.3	13.2	12.1	12.1	12.1	12.1	12.1
Total direct personnel	**150.5**	**171.6**	**150.9**	**177.5**	**177.5**	**177.5**	**177.5**	**177.5**

Table 10.5
(continued)

	FISCAL YEAR							
	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
National Aeronautics and Space Administration								
Operating expense	5.5	5.9	5.0	13.0	13.0	13.0	13.0	13.0
Technical personnel	13.7	18.5	19.1	34.0	34.0	34.0	34.0	34.0
Other direct personnel	0.3	8.5	20.0	5.2	5.2	5.2	5.2	5.2
Total direct personnel	**14.0**	**27.0**	**39.1**	**39.2**	**39.2**	**39.2**	**39.2**	**39.2**
Department of Health and Human Services								
Operating expense	5.1	4.8	6.6	6.7	6.7	6.7	6.7	6.7
Capital equipment	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total program	5.2	4.9	6.7	6.8	6.8	6.8	6.8	6.8
Technical personnel	21.2	29.6	27.5	26.3	26.3	26.3	26.3	26.3
Other direct personnel	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Total direct personnel	**21.5**	**29.8**	**27.7**	**26.5**	**26.5**	**26.5**	**26.5**	**26.5**
Environmental Protection Agency								
Operating expense	2.4	1.2	2.9	3.1	3.1	3.1	3.1	3.1
Technical personnel	12.9	14.0	16.5	16.4	16.4	16.4	16.4	16.4
Other direct personnel	0.8	0.4	0.6	0.6	0.6	0.6	0.6	0.6
Total direct personnel	**13.7**	**14.4**	**17.1**	**17.0**	**17.0**	**17.0**	**17.0**	**17.0**
National Science Foundation								
Operating expense	1.1	0.8	0.2	0.2	0.2	0.2	0.2	0.2
Technical personnel	1.5	1.3	1.4	0.9	0.9	0.9	0.9	0.9
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**1.5**	**1.3**	**1.4**	**0.9**	**0.9**	**0.9**	**0.9**	**0.9**
Federal Emergency Management Agency								
Operating expense	2.5	3.5	4.2	3.4	3.4	3.4	3.4	3.4
Technical personnel	6.1	13.5	16.0	18.3	18.3	18.3	18.3	18.3
Other direct personnel	0.8	1.0	0.9	0.9	0.9	0.9	0.9	0.9
Total direct personnel	**6.9**	**14.5**	**16.9**	**19.2**	**19.2**	**19.2**	**19.2**	**19.2**

Table 10.5
(continued)

	FISCAL YEAR							
	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Agency for International Development								
Operating expense	0.8	0.7	0.8	0.8	0.8	0.8	0.8	0.8
Technical personnel	2.8	5.2	3.8	3.6	3.6	3.6	3.6	3.6
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**2.8**	**5.2**	**3.8**	**3.6**	**3.6**	**3.6**	**3.6**	**3.6**
Other Federal Agencies								
Operating expense	4.6	(2.2)[b]	3.2	2.6	2.6	2.6	2.6	2.6
Capital equipment	0.4	0.6	0.7	0.7	0.7	0.7	0.7	0.7
Total program funding	**5.0**	**(1.6)**[b]	**3.9**	**3.3**	**3.3**	**3.3**	**3.3**	**3.3**
Technical personnel	26.2	18.0	21.5	12.3	12.3	12.3	12.3	12.3
Other direct personnel	1.2	1.8	2.2	2.2	2.2	2.2	2.2	2.2
Total direct personnel	**27.4**	**19.8**	**23.7**	**14.5**	**14.5**	**14.5**	**14.5**	**14.5**
Nonfederal Organizations Electric Power Research Institute								
Operating expense	2.7	1.1	2.0	1.8	1.8	1.8	1.8	1.8
Technical personnel	9.2	9.9	8.1	6.1	6.1	6.1	6.1	6.1
Other direct personnel	0.8	1.3	0.4	0.3	0.3	0.3	0.3	0.3
Total direct personnel	**10.0**	**11.2**	**8.5**	**6.4**	**6.4**	**6.4**	**6.4**	**6.4**
Other Nonfederal Agencies								
Operating expense	5.8	2.4	2.5	1.1	1.2	1.2	1.2	1.2
Technical personnel	14.0	16.4	12.6	7.5	7.5	7.5	7.5	7.5
Other direct personnel	1.4	0.6	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**15.4**	**17.0**	**12.6**	**7.5**	**7.5**	**7.5**	**7.5**	**7.5**
Total Work for Others[g]								
Operating expense	100.0	70.8	87.9	100.7	100.8	100.8	100.8	100.8
Capital equipment	2.8	3.1	3.3	3.3	3.3	3.3	3.3	3.3
Total program funding	**102.8**	**73.9**	**91.2**	**104.0**	**104.1**	**104.1**	**104.1**	**104.1**

Table 10.5
(continued)

	FISCAL YEAR							
	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Technical personnel	303.0	346.4	324.9	350.3	350.3	350.3	350.3	350.3
Other direct personnel	31.7	44.4	47.0	30.6	30.6	30.6	30.6	30.6
Total direct personnel	**334.7**	**390.8**	**371.9**	**380.9**	**380.9**	**380.9**	**380.9**	**380.9**
Total Program Resources								
Operating expense	485.6	554.2	802.2	889.9	888.9	897.0	905.1	913.1
Capital equipment	23.4	31.4	50.2	51.7	53.3	52.0	52.4	52.5
Construction	34.0	21.6	0.0	0.0	0.0	0.0	0.0	0.0
Total program funding	**543.0**	**607.2**[d]	**852.4**[d]	**941.6**[d]	**942.2**	**949.0**	**957.5**	**965.6**
Proposed construction	0.0	0.0	32.0	105.3	167.3	246.5	434.9	685.6
Technical personnel	1664.3	1989.2	2412.8	2503.3	2517.8	2518.3	2519.0	2519.6
Other direct personnel	157.8	280.4	410.7	392.0	392.0	392.0	392.1	392.1
Total direct personnel	**1822.1**	**2269.6**	**2823.5**	**2895.3**	**2909.8**	**2910.3**	**2911.1**	**2911.7**

[a]Inflation escalation factor for FY 1993 and FY 1994 is 4.0%. Figures for FY 1995 through FY 1998 are in constant FY 1994 dollars. BA in tables is new BA requirements as requested in the FY 1994 budget submission adjusted to incorporate any interim guidance. New BA is calculated by adding estimates of outstanding commitments and prefinancing to the total cost and then subtracting the prior-year uncosted budget.

[b]Parentheses contain negative amounts, indicating a budgetary deobligation. Without the deobligation of $6 million, the amount of BA would have been $4.4 million.

[c]Includes general-purpose equipment or general plant projects funding from KG Program.

[d]Data include several field-work proposal proposed in 1994 budget submission to cover Occupational Safety and Health Administration and other safety and health compliance needs.

[e]Budget and manpower projections are dependent on sales and revenues.

[f]Does not include DOE new production reactor (DOE-NP) funding via transfers from other DOE laboratories.

[g]Includes Nuclear Regulatory Commission. In addition, there are a few Work for Others projects that have ORNL staff as principal investigators, but part of the funding is reported through the Y-12 and K-25 financial plans.

Table 10.6

Subcontracting and procurement by fiscal year

($ in millions—obligated)

	1991	1992	1993	1994
Universities	35.5	36.6	38.6	40.2
All others	178.6	192.0	200.0	208.0
Transfers to other DOE facilities	2.5	3.7	3.0	3.1
Total external subcontracts and procurements	**216.6**	**232.3**	**241.6**	**251.3**

Table 10.7

Small and disadvantaged business procurement

by fiscal year

	1991	1992
Total ($ in millions—BA)	8.0	8.4
Annual procurement (%)	5.2	5.2

Appendix

Abbreviations

AA	affirmative action
ABET	Accrediting Board for Engineering Technology
ADS	activity data sheet
AEOD	Office for Analysis and Evaluation of Operational Data
AFM	atomic force microscope
AIC	Advanced Industrial Concepts
AID	Agency for International Development
ALERT	Associated Laboratories for Excellence in Radiation Technology
ANL	Argonne National Laboratory
ANS	Advanced Neutron Source
ARL	Army Research Laboratory
ARM	atmospheric radiation measurement
ATD	Applied Technology Division
ATF	Advanced Toroidal Facility
ATSDR	Agency for Toxic Substances and Disease Registry
B&W	Babcock and Wilcox
BA	budget authorization
BES	Basic Energy Sciences
BPX	Burning Plasma Experiment
BTESM	Building Thermal Envelope Systems and Materials
BWR	boiling water reactor
C&TD	Computing and Telecommunications Division
CAMA	Center for Advanced Microstructural Analysis
CANDU	Canadian Deuterium-Uranium Reactor
CANS	combination area neutron spectrometer
CBS	Center for Biological Sciences
C-CAP	Coast Watch Change Analysis System
CCS	Center for Computational Science
CCTP	Clean Coal Technology Program
CDIAC	Carbon Dioxide Information Analysis Center
CD—NSWC	Carderock Division—Naval Surface Warfare Center
CEF	Critical Experiments Facility
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERN	Conseil Européen pour Recherche Nucléaire
CERR	Center for Excellence in Research Reactors
CESAR	Center for Engineering Systems Advanced Research
CFC	chlorinated fluorocarbon or chlorofluorocarbon
CFRP	Consolidated Fuel Reprocessing Program
CHAMMP	Computer Hardware, Advanced Mathematics, and Model Physics
CIS	Commonwealth of Independent States
CMC	Ceramic Manufacturability Center

CORECT	Committee on Renewable Energy Commerce and Trade
CRADA	cooperative research and development agreement
CRAF	Comet Rendezvous Asteroid Flyby
CSAM	Center for Study of Advanced Materials
CSPP	Computer Systems Policy Project
CURE	chemical unit record estimates
D&D	decontamination and decommissioning
D-T	deuterium-tritium
DAAC	data center for atmospheric trace gas cycling
DARPA	Defense Advanced Research Projects Agency
DC	direct cycle
DNA	deoxyribonucleic acid
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOE-BES	U.S. Department of Energy, Office of Basic Energy Sciences
DOE-EM	U.S. Department of Energy, Office of Environmental Restoration and Waste Management
DOE-ER	U.S. Department of Energy, Energy Research
DOE-HQ	U.S. Department of Energy Headquarters
DOE-ID	U.S. Department of Energy, Idaho Falls Field Office
DOE-NE	U.S. Department of Energy, Office of Nuclear Energy
DOE-NP	U.S. Department of Energy, New Production Reactors
DOE-OR	U.S. Department of Energy, Oak Ridge Field Office
DOSAR	Dosimetry Applications Research
DOT	U.S. Department of Transportation
ECA	energy conversion area
ECAO-CIN	Environmental Criteria and Assessment Office in Cincinnati
EDP	engineering development plan
EEO	Equal Employment Opportunity
EEO/AA	Equal employment opportunity/affirmative action
EGF	epidermal growth factor
EIA	Energy Information Administration
EIS	environmental impact statement
ELSS	environmental, life, and social sciences
EMIC	Environmental Mutagen Information Center
EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
ER	environmental restoration
ERLE	Excess Research Laboratory Equipment
ES&H	environmental, safety, and health
ES&HC	environmental, safety, and health compliance
ESD	Environmental Sciences Division
ETI	Education Technology Institute
FCCSET	Federal Coordinating Council for Science, Energy, and Technology
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
FIS	fluoroimmunosensor
FTE	full-time equivalent
FUSRAP	Formerly Utilized Sites Remedial Action Project
FWP	field-work proposal
FY	fiscal year
GDR	giant dipole resonance
GEM	gamma, electron, and muon
GEM	Graduate Degrees for Minorities in Engineering, Inc.
GLCA/ACM	Great Lakes Colleges Association/Associated Colleges of the Midwest
GPE	general-purpose equipment

GPP	general plant project
GSF	gross square feet
GWPO	Groundwater Program Office
HASRD	Health and Safety Research Division
HBCU	historically black colleges and universities
HEAST	Health Effects Assessment Summary Tables
HERMIES	Hostile Environment Robotic Machine Intelligence Experiment Series
HFIR	High Flux Isotope Reactor
HGMIS	Human Genome Management Information System
HHIRF	Holifield Heavy Ion Research Facility
HPRR	Health Physics Research Reactor
HTGR	high-temperature gas-cooled reactor
HTML	High Temperature Materials Laboratory
HVAC	heating, ventilation, and air conditioning
HWR	heavy-water reactor
IAC	Information Analysis Center
ICM	interim corrective measure
INEL	Idaho National Engineering Laboratory
IRI	Industrial Research Institute
IRP	Installation Restoration Program
ITER	International Thermonuclear Experimental Reactor
JASPER	Japanese/American Shielding Program of Experimental Research
JET	Joint European Torus
LANL	Los Alamos National Laboratory
LBL	Lawrence Berkeley Laboratory
LDC	lesser developing countries
LDRD	Laboratory-Directed Research and Development
LI	line item
LLLW	liquid low-level waste
LMR	liquid-metal reactor
LWR	light-water reactor
M&O	management and operating
MAC	Military Airlift Command
MAPTIC	Manufacturing and Processing Technology Integration Center
MEI	minority education institution
MHTGR	modular high-temperature gas-cooled reactor
MIRT	minority institution research travel
MODIL	Manufacturing Operations Development and Integration Laboratory
MOU	memorandum of understanding
MS&E	Materials Science and Engineering
MSC	Military Sealift Command
MTMC	Military Traffic Management Command
MVST-CIP	Melton Valley Storage Tank Capacity Increase Project
NASA	National Aeronautics and Space Administration
NCA&TSU	North Carolina A&T State University
NCAR	National Center for Atmospheric Research
NCHGR	National Center for Human Genome Research
NCI	National Cancer Institute
NCMS	National Center for Manufacturing Science
NEPA	National Environmental Policy Act
NERC	NEPA Environmental Review and Compliance
NGB	National Guard Bureau
NIC	newly industrialized countries
NICHHD	National Institute of Child Health and Human Development
NIEHS	National Institute of Environmental Health Sciences
NIGMS	National Institute of General Medical Sciences

NIH	National Institutes of Health
NIST	National Institute for Standards and Technology
NMR	nuclear magnetic resonance
NMSS	Nuclear Material Safety and Safeguards
NPR	New Production Reactors
NRC	Nuclear Regulatory Commission
NRR	Office of Nuclear Reactor Regulation
NSF	National Science Foundation
OCRWM	Office of Civilian Radioactive Waste Management
OEA	Office of Environmental Analysis
OGUI	Office of Guest and User Interactions
OHEA	EPA's Office of Health and Environmental Assessment
OHER	Office of Health and Environmental Research
ORAU	Oak Ridge Associated Universities
ORDC	Oak Ridge Detector Center
OREIS	Oak Ridge Environmental Information System
ORELA	Oak Ridge Electron Linear Accelerator
OREN	Oak Ridge Educational Network
ORGSBS	Oak Ridge Graduate School of Biomedical Sciences
ORIC	Oak Ridge Isosynchronous Cyclotron
ORISE	Oak Ridge Institute for Science and Education
ORNL	Oak Ridge National Laboratory
ORSOAR	Oak Ridge Synchrotron Organization for Advanced Research
ORTA	Office of Research and Technology Applications
OSHA	Occupational Safety and Health Administration
OTD	Office of Technology Development
OTT	Office of Technology Transfer
PALS	Partners at the Laboratory in Science
PCA	Pool Critical Assembly
PCB	polychlorinated biphenyl
PENDOS	personnel neutron dosimeter/spectrometer
PEP	powder evacuated panel
PHENIX	Photon Electron New Heavy Ion Experiment
PICS	Partnership in Computational Science
PM-AMMOLOG	Program manager, Office for Ammunition Logistics
PNC	Power Reactor and Nuclear Fuel Development Corporation (Japan)
PPPL	Princeton Plasma Physics Laboratory
PSTM	photon scanning tunneling microscope
QA	quality assurance
R&D	research and development
RADCAL	Radiation Calibration Laboratory
RAP	Remedial Action Program
RAPIC	Remedial Action Program Information Center
RCRA	Resource Conservation and Recovery Act
REAT	renewable energy applications and training
REDC	Radiochemical Engineering Development Center
RES	NRC Office of Nuclear Regulatory Research
RETF	Recycle Equipment Test Facility
rf	radio frequency
RHIC	Relativistic Heavy-Ion Collider
RI	remedial investigation
RIB	radioactive ion beams
RISP	Robotics and Intelligent Systems Program
RMS	Recoil Mass Spectrometer
ROW	the rest of the world
RSIC	Radiation Shielding Information Center
RTG	radioisotope thermoelectric generator
S&H	safety and health

S&M	surveillance and maintenance
SACAM	Saturday Academy of Computing and Mathematics
SAHEP	Southern Association of High-Energy Physics
SARA	Service Academies Research Associates
SAS	Surveillance Data Base, Analysis, and Standardization
SC	steam cycle
SCSS	Sequence Coding and Search System
SDC	Solenoidal Detector Collaboration
SDI	Strategic Defense Initiative
SDIO	Space Defense Initiative Organization
SEED	Summer Educational Experience for the Disadvantaged
SEER	Science Education and External Relations
SEI	Space Exploration Initiative
SEPER	Science Education Programs and External Relations
SERS	Science and Engineering Research Semester
SERS	Surface-enhanced Raman spectroscopy
SFMP	Surplus Facilities Management Project
SFT	Super Fixed Target
SFUP	Strategic Facilities Utilization Program
SHaRE	Shared Research Equipment
SMAC/CRC	Surface Modification and Characterization/Collaborative Research Center
SMART	Science/Math Action for Revitalized Teachers
SSC	Superconducting Super Collider
STAR	Summer Teachers as Resources
STEM	scanning transmission electron microscope
STM	scanning tunneling microscope
STRIVE	Science Teachers' Research for Vital Involvement
SURA	Southeastern Universities Research Association
TAB	technology applications bulletin
TFTR	Tokamak Fusion Test Reactor
TIRC	Toxicology Information Response Center
TOPO	Transportation Operations Project Office
TQM	Total Quality Management
TRA	Teacher Research Associates
TRU	transuranic
TSNT	steady-state neutron tokamak
TSR	Tower Shielding Reactor
TST	steady-state tokamak
TVA	Tennessee Valley Authority
UMTRAP	Uranium Mill Tailings Remedial Action Project
USDA	U.S. Department of Agriculture
U.S.S.R.	Union of Soviet Socialist Republics
USTRANSCOM	United States Transportation Command
UT	The University of Tennessee
UTK	The University of Tennessee, Knoxville
UV-B	ultraviolet-B
WAG	waste area grouping
WFO	Work for Others
WHPP	Waste Handling and Packaging Plant
WIPP	Waste Isolation Pilot Plant
WM	waste management
WMRAD	Waste Management and Remedial Action Division
WRP	Waste Reduction Program
WVNS	West Valley Nuclear Services

Acknowledgments

The Office of Planning and Management gratefully acknowledges the efforts of all those who contributed to the preparation of the Laboratory's institutional plan.

Guidance from DOE Headquarters, particularly as a result of the On-Site Review, helped shape this plan. Special appreciation goes to Stephen G. Buswell for coordinating these efforts. In addition, DOE-ER staff provided guidance at each stage of the planning process. Special appreciation goes to Pamela I. Gorman for coordinating these efforts.

We also thank those ORNL staff members who have contributed to the production of this document: Walter S. Koncinski, Jr., for editing, coordinating, and managing production; Larry W. Davis, makeup artist; Sandi Lyttle, electronic publisher; graphic artists; photographers; and Joseph H. Lovell, for financial resources data.

In the Office of Planning and Management, we would like to thank Sybil T. Wyatt, for writing and creation of document design; Joseph Greeley, Janet Dippo, and Kathy Sharp for office support.

Amanda

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