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OAK RIDGE NATIONAL LABORATORY institutional plan

FY 1992–FY 1997

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Oak Ridge National Laboratory Institutional Plan FY 1992–FY 1997

Date Published—November 1991

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Oak Ridge, Tennessee 37831-6285
managed by
Martin Marietta Energy Systems, Inc.
for the
U.S. Department of Energy
under Contract DE-AC05-84OR21400

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1. laboratory director's statement

1. Laboratory Director's Statement

Energy, environment, economic competitiveness, and education. Increasingly of interest and concern to the nation as a whole, these subjects are the focus of considerable attention by the U.S. Department of Energy (DOE) and its national laboratories.

Oak Ridge National Laboratory (ORNL) has been making and will continue to make important scientific and technical contributions in each of these areas. However, doing so requires the kind of broad-based programs in the basic and applied sciences that span the range of traditional disciplines. Success also requires the proper complement of essential tools such as computers, laboratory instruments, and key user facilities such as the Advanced Neutron Source.

The Institutional Plan that follows describes much of the work the Laboratory plans to conduct in these and other areas of basic research and applied technology.

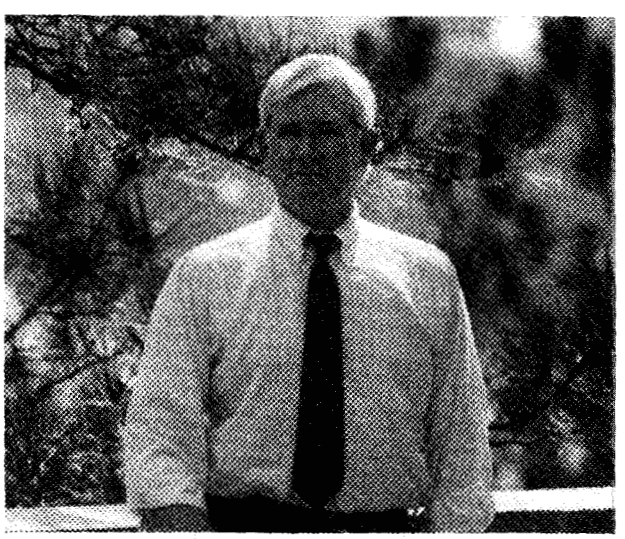
Energy

At no time since the 1973 oil embargo has the need for U.S. energy security been more apparent than during this past year. If it was not already clear, recent events in the Persian Gulf should have established beyond doubt that dependence on foreign oil poses a serious risk to this nation and to world political stability.

A well-balanced and stable program for exploring and developing various energy production and use options is therefore an essential component of a national energy strategy. The elements of such a program should not be based on ideological principles, but should focus on a mix of both near- and long-term strategies that have a realistic chance of making a significant difference. These include energy efficiency and such nonfossil technologies as passively safe nuclear power reactors, sustainable high-yield biomass sources, and magnetic fusion.

Environmental Protection

In recent years, energy issues have become interwoven with the environmental problems caused by our energy choices, principally those related to the production and use of fossil fuels. About 87% of U.S. energy needs are met by oil, coal, and natural gas. Worldwide, combustion of these fuels contributes to a variety of problems and potential problems, including the greenhouse effect, acid deposition, and regional air pollution. Also, concern about the health and safety ramifications of nuclear power generation and waste disposal remains high both here and abroad.



ORNL Director Alvin W. Trivelpiece.

Given this situation in the context of dramatic population growth over the next half-century, it is imperative that we concentrate attention on obtaining solutions to energy-related environmental issues including those of developing nations where energy technology choices will be crucial in determining local, regional, and global pollution. ORNL is a major contributor both to developing better energy technologies and a better understanding of environmental problems.

Economic Competitiveness

Energy-related products are the biggest contributors to the nation's balance-of-trade deficit, with fuel and motor vehicle imports representing the two top sources of the imbalance. However, just as energy consumption drives these economic problems, so can energy research and development (R&D) contribute to the solution. Energy R&D is one of the keys to developing products and technologies that make U.S. industry more efficient at home and more competitive abroad. Energy R&D also stimulates the economy directly by serving as the impetus for entrepreneurial spin-offs and indirectly by building a technology base so broad that it contributes to the economy as a whole.

One important way ORNL and DOE's other national laboratories can help improve the U.S. competitive position in the world economy is by finding ways to share our expertise with those who can use it. Elements of this strategy include federal user facilities, the licensing of products and processes developed in our laboratories, direct technical assistance, cooperative research and development agreements, and commercial spin-offs.

Education

With approximately 25,000 scientists and engineers employed in its facilities, DOE is a "consumer" of talent. With an apparent shortage of such talent looming, it is appropriate that DOE do its share to help "produce" talent by inspiring our young people to pursue careers in science, mathematics, and engineering. It can do this in a variety of ways, such as by providing opportunities for students to get involved in research through summer programs and visits to the laboratories. Promoting education is perhaps even more crucial to our competitiveness than technology transfer.

Education of both the general public and the scientific community is going to be required to meet the challenges of our increasingly complex technically oriented world. ORNL and other DOE laboratories are pursuing two important educational objectives: strengthening science and mathematics education across the board and providing technically accurate, nonbiased information to help the public make wise, realistic energy choices. Perhaps even more important, however, is our role in nurturing and maintaining a highly educated research community capable of meeting the challenges ahead.

Just as the issues of energy, the environment, competitiveness, and education are interrelated, so are the solutions. The following plan reflects the high priority ORNL places on the integration of these issues and presents the most effective tactics for addressing them.

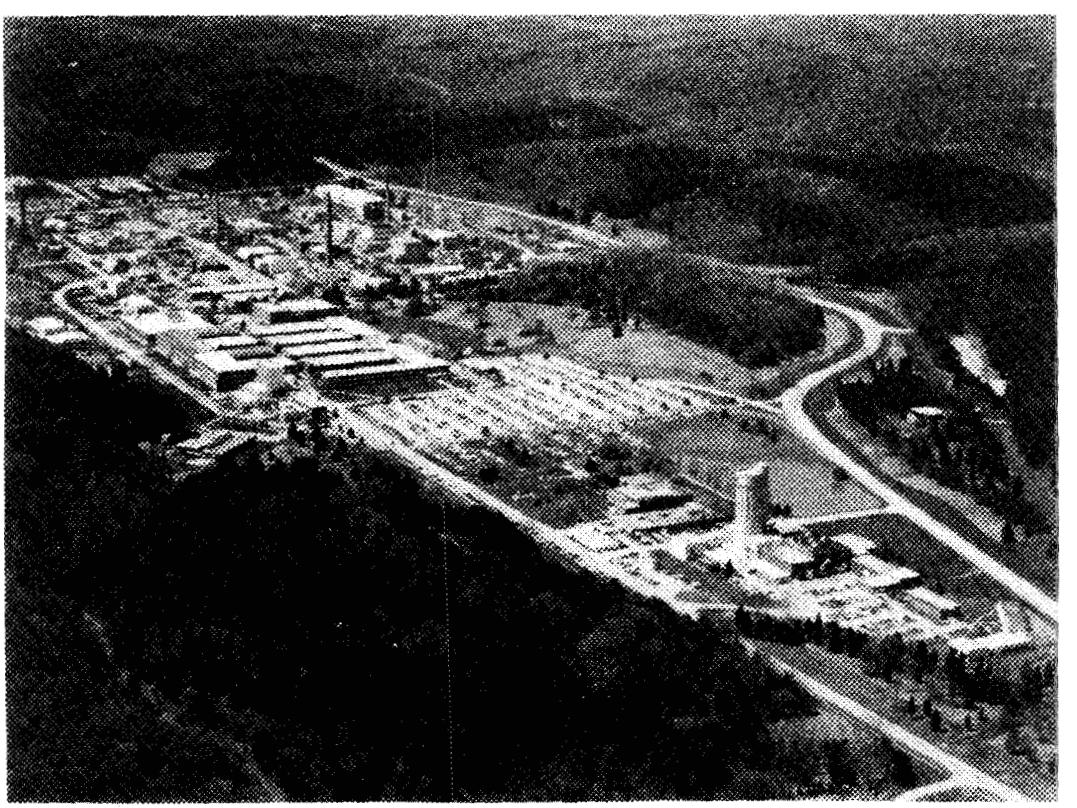
2. laboratory missions

2. Laboratory Missions

The Oak Ridge National Laboratory (ORNL) is managed by Martin Marietta Energy Systems, Inc., for the U.S. Department of Energy (DOE). ORNL is one of DOE's major multiprogram national laboratories. Activities at the Laboratory are focused on basic and applied research, on technology development, and on other technological challenges that are important to DOE and to the nation. The Laboratory also performs research and development (R&D) for non-DOE sponsors when such activities complement DOE missions and address important national or international issues.

The Laboratory is committed to the pursuit of excellence in all its activities, including the commitment to carry out its missions in compliance with environmental, safety, and health laws and regulations. The principal elements of the Laboratory's missions in support of DOE include activities in each of the following areas:

- **Energy production and conservation technologies.** The Laboratory conducts applied R&D in energy technologies—in



An aerial view of the Oak Ridge National Laboratory.

conservation, fission, magnetic fusion, renewable resources, and fossil energy.

- **Physical and life sciences.** Experimental and theoretical research is undertaken to investigate fundamental problems in physical, chemical, materials, computational, biomedical, earth, environmental, and social sciences; to advance scientific knowledge; and to lay the foundation for other technologies of national significance.
- **Scientific and technological user facilities.** ORNL designs, builds, and operates unique research facilities for the benefit of university, industrial, other federal agency, and national laboratory researchers. The Laboratory brings national and international research elements together for important scientific and technical collaborations.
- **Environmental protection and waste management.** ORNL develops technologies to correct existing environmental problems, to prevent future problems, and to reduce waste generation.
- **Science and technology transfer.** The transfer of science and technology to U.S. industries and universities, a key factor in increasing the nation's international competitiveness, is an integral component of ORNL's R&D missions.
- **Education.** ORNL helps to prepare the scientific and technical work force of the future by offering innovative and varied learning and R&D experiences at the Laboratory to students and faculty members from the preschool level through postdoctoral studies and by establishing new relationships (i.e., partnerships) with educational institutions from elementary schools to universities.

3. laboratory strategic plan

3. Laboratory Strategic Plan

Oak Ridge National Laboratory (ORNL) is one of the major multiprogram laboratories owned by the U.S. Department of Energy (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, environment, and 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.

Planning Assumptions

As a result of the recent events in the Middle East, energy has become a grave national concern once again. In response, energy research and development (R&D) funding may receive a boost over the next few years. 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 DOE's largest energy research laboratory, we are in a good position to make major contributions to DOE's programs in energy R&D.

As 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 mankind'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 assume increasing national importance 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 passing fad. 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 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, which birthed the national laboratories nearly a half century ago. It 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 decrease 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 and the Burning Plasma Experiment 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.

Program Trends at ORNL

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, environment, and 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. ORNL currently hosts over 2900 guest researchers each year; by the turn of the century, we expect that number to double. 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; and the Materials Science and Engineering 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, universities, and

other R&D organizations 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, managed by Martin Marietta Energy Systems, Inc. (Energy Systems), 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 mid-1991, the Laboratory had in place 53 licensing agreements with American industry. The cumulative product sales associated with these agreements is $40 million and 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 30 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 Ecological and Physical Sciences Study Center, which attracted 16,000 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), nonfossil energy supply technologies (including fission and fusion energy), and waste R&D. 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 11 CRADAs thus far—39% of the total now being developed at ORNL.

Two major user centers are supported by the conservation work: the High Temperature Materials Laboratory 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.

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.

Energy supply technology development at ORNL will continue to concentrate on fusion and fission. The energy released when light elements are "fused" offers mankind 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.

ORNL plans to continue a leading 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. ORNL's current role in DOE's space reactor program includes production of the encapsulation hardware for the radioisotope thermoelectric generators (RTGs) and materials development for the SP-100 Program. The RTGs power the current generation of space exploration satellites, and the SP-100 reactor is being designed and developed for future missions requiring higher power levels than RTGs and solar panels can produce.

ORNL also has a lead role in technology development for DOE's New Production Reactors (NPR) Program. Two new reactors are being designed for this program: the heavy-water reactor and the MHTGR. NPR, DOE's highest priority program, is expected to have new production capacity on-line by the end of this decade. The commercial and NPR versions of the MHTGR both operate on the steam cycle (SC) in which hot helium gas from the reactor passes through a steam generator (i.e., gas-to-water heat exchanger) and produces steam to drive a turbine.

ORNL has for many years worked on the high-temperature gas-cooled reactor (HTGR) concept. We continue to regard this reactor, now in a modular 135-MW(e) size, as a most promising advanced reactor concept because of its safety characteristics, its usefulness in generating heat for processing, and its simplicity of operation. One of the drawbacks of the HTGR has been the high capital cost resulting in high power costs. We are now working with the Massachusetts Institute of Technology to examine an advanced HTGR where the SC is replaced by a gas turbine driven directly by the helium coolant gas. This system appears to offer very significant cost advantages and may very well reduce the cost of power from HTGRs to make it very attractive to utilities.

Another new programmatic initiative relates to the Space Exploration Initiative (SEI). During FY 1991 ORNL will contribute to a technology assessment to support nuclear propulsion. ORNL's goal is to be assigned technical responsibility in the areas where the Laboratory is already contributing to DOE's advanced power reactor program and space reactor program. SEI will likely be the next "big science" project for the U.S. scientific community, and nuclear propulsion is just one of several areas, such as robotics, in which ORNL can contribute.

Fossil energy R&D focuses on materials R&D; environmental, safety, and health (ES&H) activities; bioprocessing of coal to produce liquid or gaseous fuels; combustion research; and modeling activities on the operational requirements for the Strategic Petroleum Reserve. Materials R&D covers research on ceramic composites, advanced austenitic alloys, iron aluminides, corrosion-resistant alloys, and the mechanisms of erosion and corrosion. Advanced ceramic membranes, ceramic composites, and alloys are examined for gas separation and filtration applications.

The Laboratory is aggressively pursuing initiatives in the waste R&D area. 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. The materials systems studied include semiconductors, superconductors, metals and alloys, ceramics, polymers and composites (with particular emphasis on synthesis and processing of advanced materials). 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 medical and military applications, and structural biology research continue at the High Flux Isotope Reactor. 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 are heavily dependent on the ANS project.

An area of increasing emphasis will be in computational science: developing and utilizing massively parallel computers. A new center for computational sciences will be added to support existing computational efforts, and 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; man-machine symbiosis is the ultimate goal.

Chemistry and chemical-engineering research will emphasize separation science and technology, photochemistry and biophotochemistry, and biochemical-engineering research. 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) would make ORNL the 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, improvements in the highly stripped heavy ion facility, and continued ion-source and acceleration improvements. The HHIRF, a user facility, provides investigators from across the nation world-class opportunities for nuclear-structure research. It is also an important national facility for promoting graduate and undergraduate education in nuclear physics.

Environmental, Life, and Social Sciences

Biological, environmental, and health sciences will continue to prosper as essential elements of the Laboratory's research programs. 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 Center for Biological Sciences 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 forming a new center of risk management, improving the understanding of pollutant interactions at the atomic and molecular levels, enhancing studies of the liquid state of matter, 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 (i.e., energy and resource analysis, National Environmental Policy Act program management, research on waste management and emergency preparedness, and energy analysis of developing countries); research on energy conservation technologies (i.e., building equipment, building envelopes, electric power systems, and existing buildings); and extensive 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 as well as to other federal and nonfederal agencies. Over the past two decades our Work for Others 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 U.S. Department of Defense agencies, but in recent years a shift to such agencies as the National Aeronautics and Space Administration (NASA), the U.S. Environmental Protection Agency, and the U.S. Department of Transportation has begun. We anticipate making significant contributions to NASA's Mission to Planet Earth and other programs.

Managerial Implications

Progress in the thematic areas of energy, environment, and 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 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 Life Sciences Complex is also a high-priority facility need.

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.

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

4. summary of major initiatives

4. Summary of Major Initiatives

Advanced Neutron Source

The Advanced Neutron Source (ANS) 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. A portion of the mission needs of the ANS is currently provided by the High Flux Isotope Reactor (HFIR) and the High Flux Beam Reactor; however, these existing facilities are 25 years old, and it would not be economical to modify them to meet effectively future neutron research needs. 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 U.S. Department of Energy (DOE) laboratories, the National Institute for Standards and Technology, universities, and industries. The National 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 goals, it is necessary to design and to construct a small, high-specific-power reactor with a nominal thermal power of ~350 MW. The design of such a reactor presents technical challenges, particularly associated with heat removal from the fuel and from components located near the core, but minimum performance goals can be achieved without reliance on new technologies. However, research and development (R&D) programs are being pursued to confirm performance data under ANS conditions, to refine existing technologies, and to develop new options for the ANS that will significantly improve reactor performance and/or safety margins (Fig. 4.1). These R&D activities include

- reactor core development to optimize the neutron flux available for research and irradiation programs and to maximize safety margins,
- corrosion tests and analyses to understand and reduce aluminum corrosion with its deleterious effects on heat removal from the fuel (Fig. 4.2),
- fuel development to confirm the performance capabilities of the uranium silicide fuel,
- core flow tests to confirm the stability of fuel plates subjected to the high coolant velocities associated with full power operation, and
- beam tube, guide, and instrument development to optimize the transport and utilization of neutrons from the core.

The R&D program has been structured such that results of the research are made available at the appropriate time for inclusion in the facility design.

The ANS has been supported through the DOE Office of Basic Energy Sciences (DOE-BES). The project schedule indicates that reactor startup would occur late in FY 2000; this approximately coincides with the estimated end of useful life for the existing reactors. A conceptual design has been initiated, and a report is scheduled for completion in late FY 1992. During the past year a conceptual design-phase reference core and reference design for the primary and secondary cooling systems were defined and documented. Preliminary projections for the total project construction-phase cost range from $800 million to $900 million (actual year dollars). Table 4.1 includes detailed budget projections.

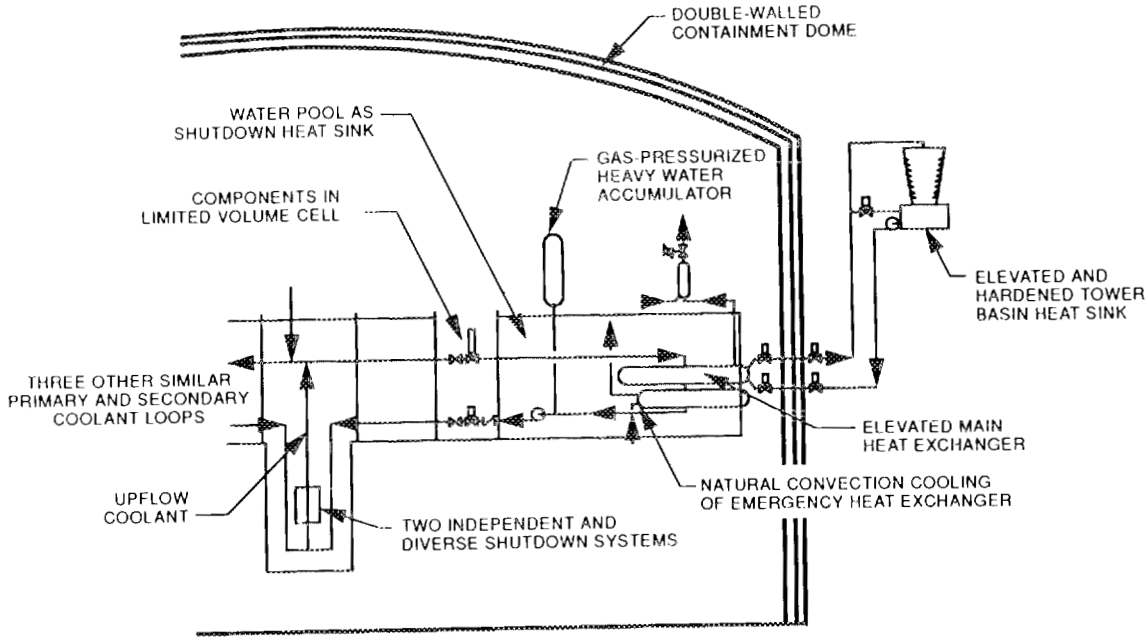


Fig. 4.1. Some safety features of the Advanced Neutron Source reactor design.

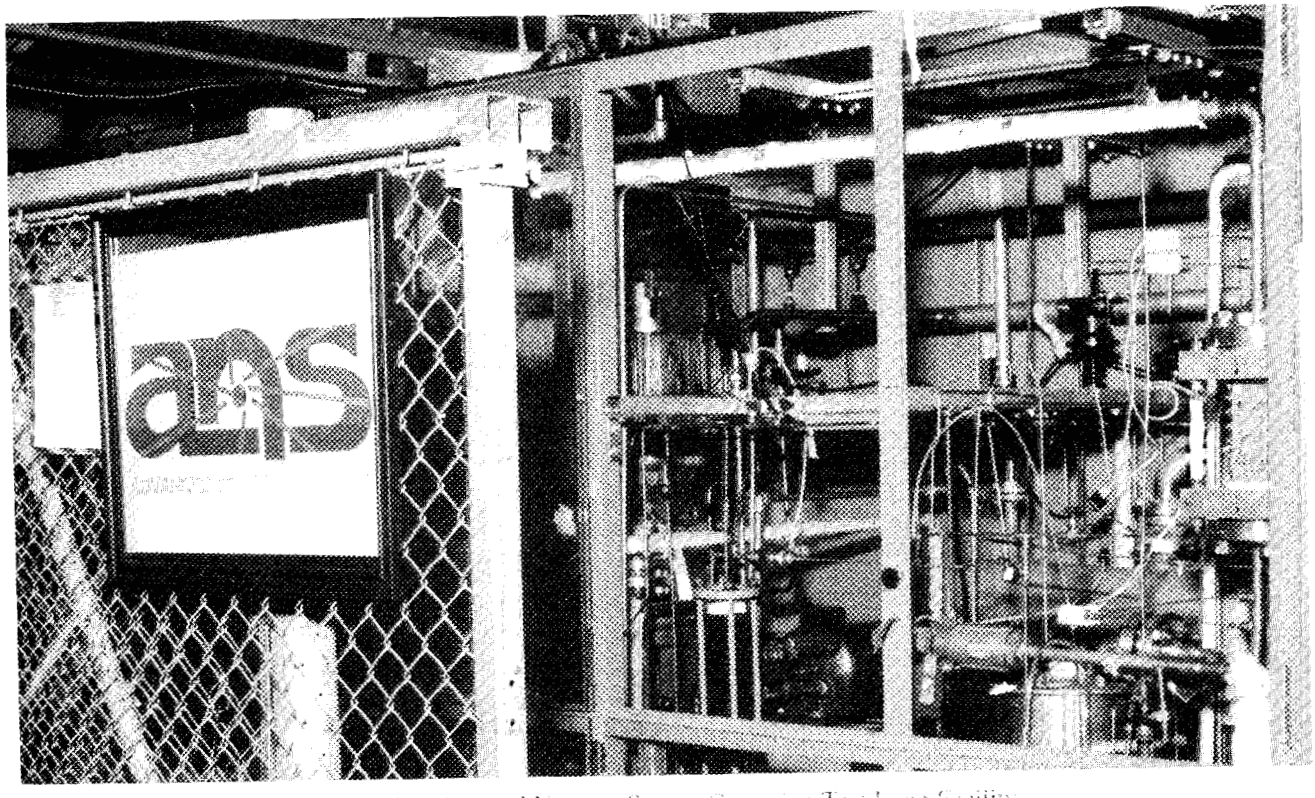


Fig. 4.2. Advanced Neutron Source Corrosion Test Loop Facility.

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

	1992	1993	1994	1995	1996	1997
Operating expense	23.6	7.2	8.0	8.6	10.4	13.8
Capital equipment	1.0	1.0	1.3	1.7	2.2	2.3
Design-only line item		38.9				
Construction line item			*a*	*a*	*a*	*a*
Total	**24.6**	**47.1**	*a*	*a*	*a*	*a*

[a]To be determined during the conceptual design phase.

Design and construction of a reactor that will meet all of the performance criteria is considered feasible. The need for early documentation of safety analyses, and for preparation of the environmental impact statement before a commitment of detailed design, prompts a phased approach to the project. Structured as a 1-year design-only phase (FY 1993) followed by a design completion and construction phase (FY 1994–FY 2000), the ANS provides an FY 2000 goal for reactor startup; design is to proceed 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.

The design of ANS continues to be guided by the future needs of the neutron science community, who will be the ultimate users. Regular meetings and workshops are held with the National Steering Committee for ANS and other review groups to assimilate their input and to advise them of design progress.

Life Sciences Complex

The development of the Oak Ridge National Laboratory (ORNL) Life Sciences Complex has been a vision of the Laboratory for many years (Fig. 4.3). The expansion of the west end area of ORNL is of extreme importance to accommodate the growing programs within the life sciences and will support DOE's increasing emphasis on environmental, safety, and health activities. The Life Sciences Complex will provide new high-tech laboratories for expanding research and development (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. Construction will consist of three line items (i.e., the Center for Biological Sciences, the Advanced Environmental Photonics Laboratory, and the Earth Systems Facility) and general plant project (GPP) upgrades. Our programmatic emphasis will be on mammalian genetics, waste R&D, global sciences, and energy efficiency.

Center for Biological Sciences

The ORNL Biology Division is at the forefront of molecular genetics using advances in genetic engineering and recombinant deoxyribonucleic acid (DNA) technology to study the mammalian genome. Recombinant DNA technology is used in characterizing cancer-causing genes, clarifying the mechanisms responsible for regulating gene expression, producing large quantities of scarce proteins for structural studies, designing new proteins that do not exist in nature, mapping mammalian chromosomes, and generating new

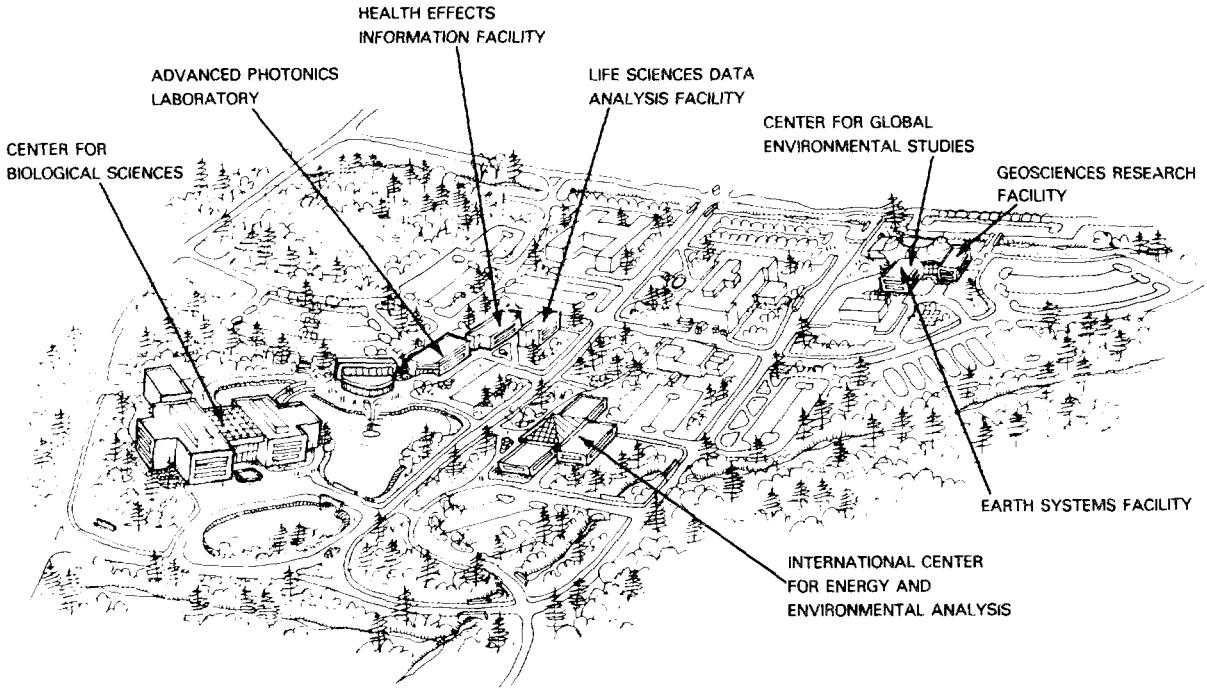


Fig. 4.3. Conceptual plan for the ORNL Life Sciences Complex (West End Development Area).

strains of mice—all of which provide techniques for genetic mapping and future gene therapy.

Structural biology, another ripe area for major significant scientific advances, will receive increased emphasis in the division. Structure ultimately determines biological function; thus sophisticated new physical tools for understanding structure at the detailed molecular level are under development, one of which is the ANS. Requested by DOE for ORNL, the ANS will permit precise determination of biological structure by neutron scattering. It will be located at the Oak Ridge X-10 Site, and the structural studies facilitated by it and other physical approaches will involve close collaboration with ORNL physical scientists. The Biology Division's current 8-mile separation from the ORNL site is a serious impediment to such collaboration. Moreover, the ANS will form the core of a major user facility; its potential to solve biological problems will attract biologists worldwide including investigators from sensitive countries who for security reasons are now essentially excluded from the division at its current Oak Ridge Y-12 Site.

The antiquated state of the Biology Division's current facilities poses an increasingly serious impediment to current research programs—not to mention an impediment to the growth and development of new initiatives. The buildings, now almost 50 years old, were originally designed as uranium-processing structures and not as biological research laboratories. The deterioration of the facilities forces diversion of an increasing fraction of research dollars into totally nonproductive avenues, causes serious delays in research programs (and in some cases precludes them), and compounds the difficulty of retaining the current scientific staff and attracting the bright young scientists required for continuing the division's excellence in research. Retrofitting the existing facilities would exceed the cost of new facilities and would seriously disrupt ongoing research programs. As the building systems continue to age, more of the burden of maintaining their functions will shift to research budgets, and the funds expended will become unavailable for research.

The initiative is to obtain FY 1993 line-item funding for the construction of a new Center for

Biological Sciences in the Life Sciences Complex of the West End Development Area of ORNL (Fig. 4.4). It will be a two-story steel frame and masonry structure, about 250,000 ft^2 in size. The building 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 (Fig. 4.5). The two above-ground floors of the wings will be the primary research areas; support functions will be located in the basement. The research areas of the building and the animal facilities will consist of successive, identical modules to provide maximum flexibility in initial layout as well as rapid and inexpensive response to future changes in programmatic directions. To minimize the building's energy demands, the design will emphasize conservation; it will also meet DOE's environmental and health and safety goals in a cost-effective way.

The design and location of the new facility will serve multiple functions. For the first time in many years, the Biology Division will be located in facilities that are suitable for the quality of research that the division has conducted for decades. State-of-the-art facilities will enhance the Biology Division's ability to compete effectively with other research institutions in attracting the outstanding young scientists required for an institution to maintain scientific leadership. User facilities will be available for guest scientists in areas such as structural biology, "transgenic" mouse production and breeding, and mapping and engineering of macromolecules. Provisions will be made for the highly successful University of Tennessee–Oak Ridge Graduate School of Biomedical Sciences,

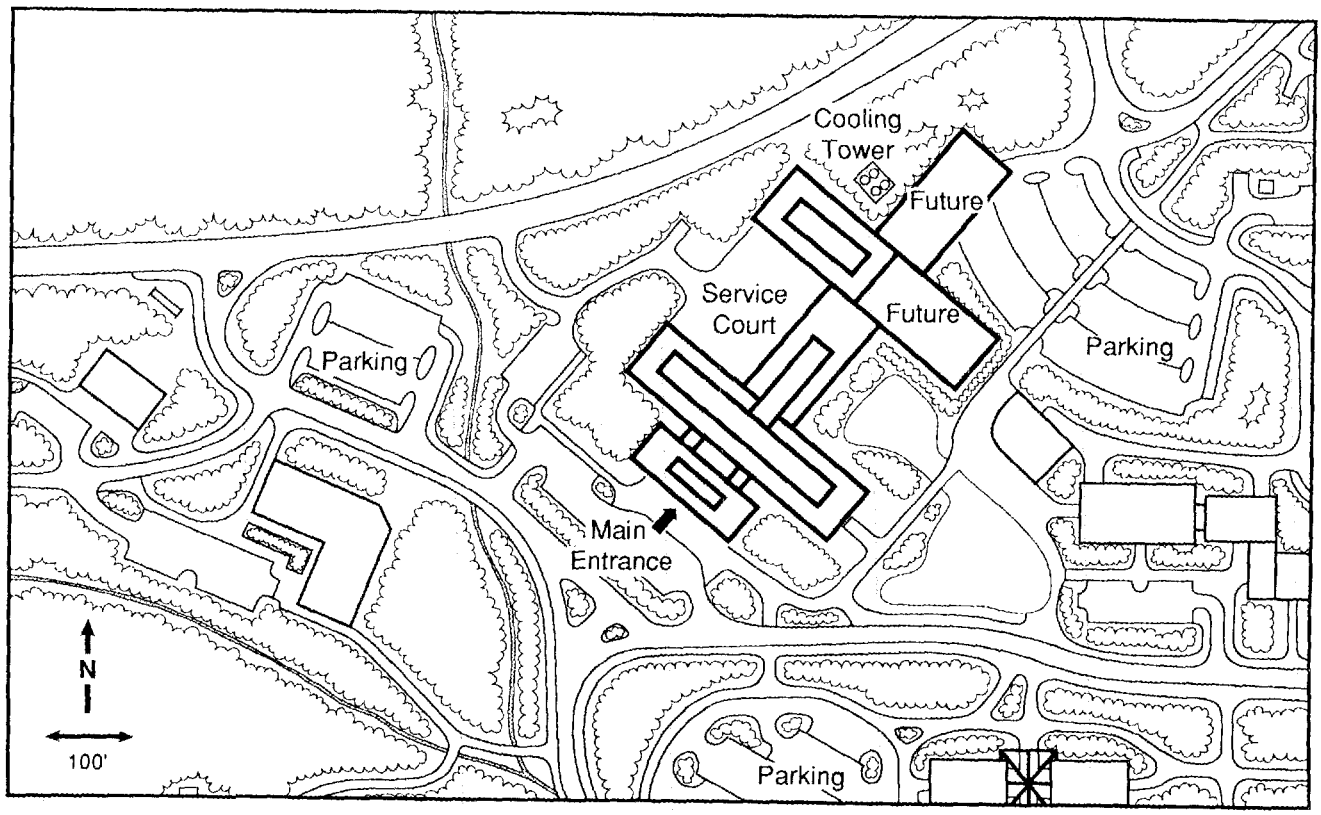
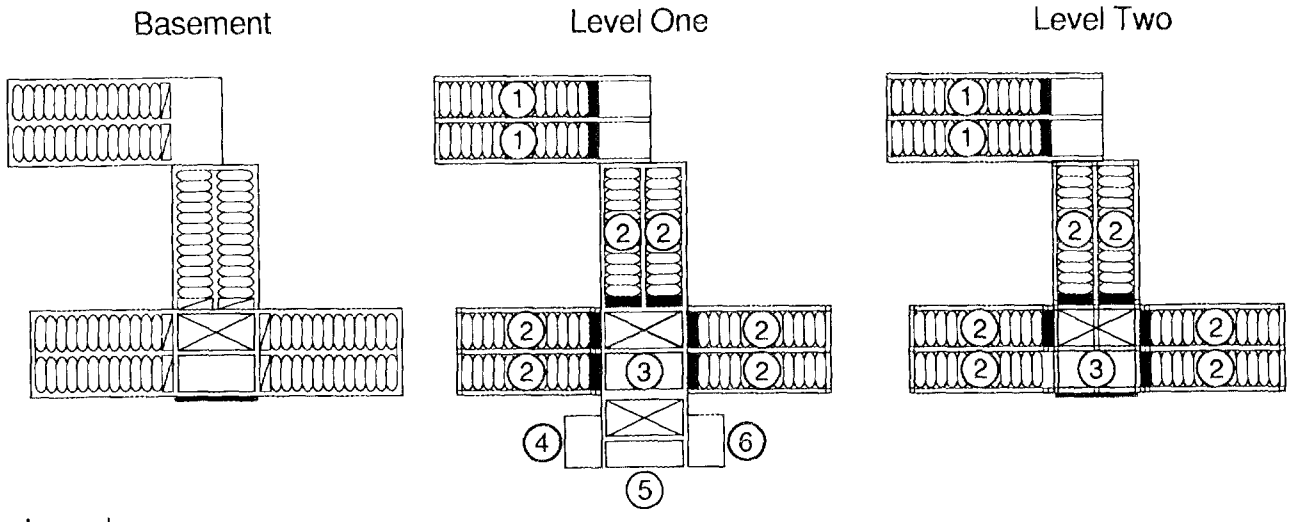


Fig. 4.4. Conceptual drawing of the Center for Biological Sciences (West End Development Area).



Legend:
1. Animal Facilities
2. Laboratories
3. Administration
4. Dining Area
5. Graduate School
6. Library

Fig. 4.5. Schematic showing levels and interconnecting wings of the proposed Center for Biological Sciences.

which has been located in and operated by the Biology Division for more than two decades. Facility-related costs for maintenance and utility services and for environmental, safety, and health will be significantly lower in the new facilities, which will release operating funds for research. The location of the division on the X-10 Site will enhance its staff members' ability to collaborate scientifically with other ORNL life science divisions and to interact effectively with major ORNL facilities such as the ANS.

The estimated $110 million total cost of the new facility lies well within the range of comparable modern biological research facilities constructed by DOE, other government agencies, and the private sector. The gross square footage (~250,000 ft^2) was derived by using widely accepted planning standards for establishing space requirements for laboratories with given numbers of investigators and space requirements for very large animal facilities, which underpin much of the division's genome research. A conceptual design has been completed, approved by the DOE Oak Ridge Field Office, and forwarded to DOE Headquarters. Funding has been requested for pre-Title I planning for the Center for Biological Sciences for FY 1992 and FY 1993.

Transgenic Mouse Facility

This existing facility has achieved prominence for producing and breeding new mutant mouse strains. ORNL is a leader in producing transgenic mice with insertional mutations—mutations triggered by inserting foreign DNA "markers" into mouse zygote chromosomes. Some transgenic mice exhibit mutations that can be correlated with disease-producing mutations in humans. By developing many additional lines of transgenic mice, ORNL's breeding center can arm many researchers with powerful new tools for deciphering the structure and function of the human genome.

Macromolecular Mapping and Engineering Facility

This proposed facility, coupled with existing ORNL research reactors but obligatorily dependent upon fruition of the ANS, will allow researchers from universities and other institutions throughout the world to probe the three-dimensional structure of proteins and other complex hydrogen-containing molecules. Unique insights into protein function will be gained through structural studies of "designer proteins" created by genetic engineering. This facility will reveal a new level of molecular detail inaccessible to X-ray techniques and beyond the reach of today's neutron-scattering equipment.

Bioprocessing Research Facility

In this biotechnology user facility, already housed at the Laboratory's main site, advanced bioreactor systems are developed for converting biomass into fuels and chemicals, turning conventional fossil fuels into clean-burning liquids and gases, and treating solid, liquid, and gaseous wastes. By bringing the Laboratory's biological researchers and analytical equipment into closer contact with the bioprocessing facility, we will forge strong new bonds both within the Laboratory itself and with additional guest researchers from universities and industries.

Mouse-Breeding Center for Human-Disease Models

In addition to breeding transgenic mice, researchers in the new facilities will generate and breed radiation- and chemical-induced mutations that are valuable for DNA-mapping studies, for discovering and exploiting homologies of the mouse and human genomes, and for assigning developmental function to DNA sequences. The facility will, in addition, be a center for breeding strains of agent-induced mutations that provide animal models for exploring serious human diseases including skeletal deformities, kidney disease, some forms of diabetes, and immune-system malfunctions.

Advanced Environmental Photonics Laboratory

The Advanced Environmental Photonics Laboratory (AEPL) will serve as a focal point for integrating currently diverse activities involving photonic devices such as lasers, fiber optics, spectrometers, and detectors. Such devices are increasingly used in characterizing and monitoring during energy production, in defense operations, and in DOE's accelerated program for environmental restoration and waste management and biological research. The entire field of photonics is in a state of flux: rapid advances are being made in rugged and inexpensive solid state lasers having increased and new frequency capabilities. New phenomena in nonlinear optics, together with developing spectroscopic approaches such as surface-enhanced and Raman and X-ray microholography, are ripe for exploiting and applying to areas such as robotics, in situ fiber-optic sensing of contaminants in the subsurface environment, and rapid identification and resolution of base units in sequencing the human genome. The AEPL will act as catalyst for accelerating these advances and producing new techniques and devices that will bear on specific DOE problems and new DOE initiatives.

The AEPL will bring diverse scientists into close contact as they develop new lasers, fiber optics, spectroscopic systems, and field-monitoring devices. The laboratory rooms will house lasers, optical benches, instrumental assembly and testing facilities, and facilities for simulating environmental test situations together with attendant environmental chambers and the necessities for validation and intercomparison testing. Multiagency activities will be accommodated in the AEPL. The laboratory space and flexibility of design and layout will be ideal for expansion of DOE programs in environmental restoration and waste management and human genome studies; U.S. Department of Defense programs in installation restoration and

weapon reduction, destruction, and verification; and the U.S. Environmental Protection Agency's Environmental Systems laboratories programs in hazardous waste.

Earth Systems Facility

For the next several decades the global environment will be center stage. The analysis of global environmental issues and the necessity to regulate the global commons will kindle international environmental debates. To manage international disagreements, integrating analyses of biophysical, social, and economic considerations must be merged through earth systems models to bridge the interdisciplinary gaps that prevent us from understanding the earth as a set of complex and interacting systems. To assist in this goal, it is time for ORNL to consolidate the interdisciplinary talents of ORNL researchers in global change. It is time for ORNL to build and to promote the interdisciplinary teams that can tackle the long-range goal of building an earth systems model. It is time for us to combine an integrating facility with our world-class global change researchers.

By establishing the Earth Systems Facility, ORNL will continue to play a pivotal role in the advancement of understanding earth systems. The facility will be structured, physically and organizationally, to promote accessibility, collaborative research, and user interactions. As a result, the facility itself will become a powerful new tool for applying ORNL's scientific expertise to help guide the management of the planet on which we live.

It will be a 50,000-ft^2 laboratory facility containing specialized computer capabilities, wet labs, staging areas, and related support space specifically designed to support our global change research program activities. Particular emphasis will be placed on creating work space that supports the interdisciplinary nature of the research including biogeochemical cycling research and modeling, solid earth processes, climatology and hydrology, and assessment capabilities (e.g., stable element laboratories, geographic information system work areas, and data-archiving systems for DOE's U.S. Atmospheric Radiation Measurement Program).

Budget Requirements

Conceptual design has been completed and approved for the proposed Center for Biological Sciences as an FY 1993 line-item construction project. The center, the first step in relocating the entire Biology Division, will provide the resources required for advanced-level molecular genetics research. The buildings will be a cost-effective modular design (i.e., having one-time engineering and design costs). In addition to the estimated $110 million in Environmental Research and Development (KP) Program construction for the center, other KP-funded line-item projects are planned, for a total KP funding level for construction of about $136 million. Investments are planned to support $4.5 million in GPP projects in the Life Sciences Complex, $9 million in steam-system upgrades for the West End, and about $4 million in other construction funds. Table 4.2 provides a detailed budget breakdown of the proposed Life Sciences Complex development.

Materials Science and Engineering Complex

The ORNL Materials Science and Engineering (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 early 1990s in the undeveloped foothills area to the east of the present X-10 Site (Fig. 4.6). The MS&E Complex will include a new Solid State Sciences Building, a Center for Advanced Microstructural Analysis, a Center for Study of Advanced Materials, a Composite Materials Laboratory, and an Office of Guest and User Interactions (OGUI). The plan of the complex addresses identified national, regional, and local

Table 4.2. Budget projections by fiscal year for the Life Sciences Complex development
($ in millions—BA)

	1992	1993	1994	1995	1996	1997
	OP[a]/CE[b]	OP/CE	OP/CE	OP/CE	OP/CE	OP/CE
Program KP						
Center for Biological Sciences[c]	0.4/0	0.4/20	0/45	0/40	0/5	
Advanced Environmental Photonics Laboratory				0/1.5	0/6.5	
Earth Systems Facility			0/2.0	0/7.0	0/3.0	
Program AT (General Plant Projects)[e]						
Data Analysis Facility	0/1.1[d]					
West roads and parking improvements		0/0.1				
Health Effects Information Facility	0/1.1					
Geosciences Research Laboratory		0/1.1				
Global Environmental Studies Center			0/1.1			
Other Construction						
International Center for Energy and Environmental Analysis	0/0.54	0/0.78	0/1.02	0/0.72	0/0.72	0/0.48
Program KG (capital costs only)						
Steam system upgrade, West End	0/1.1	0/5.0	0/2.9			

[a]Operating expense.
[b]Capital equipment.
[c]The budget projection for the Center for Biological Sciences reflects the current budget submission, which assumes construction starts in FY 1993.
[d]Approved by ORNL and DOE-OR as a general plant project for FY 1990.

needs for materials R&D, and it will support ORNL's rapidly expanding user programs and technology transfer activities. The existing OGUI will be sited in the complex to coordinate the administration of ORNL's many user activities. The Center for Study of Advanced Materials 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 replace deteriorated buildings and to alleviate 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 Sciences Building will satisfy the need for modern solid state laboratories at substantially lower cost than refurbishing existing structures to meet present Environment, Safety, and Health and Occupational Safety and Health Administration standards. The Center for Advanced Microstructural Analysis 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

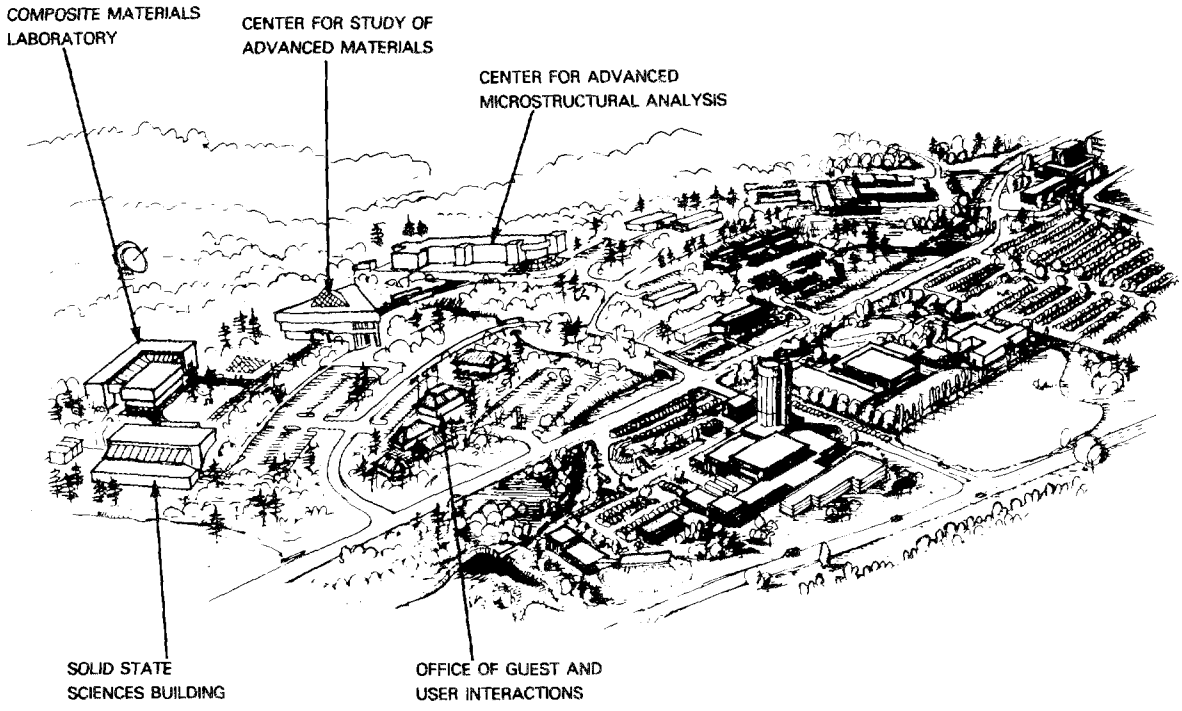


Fig. 1.6. Proposed Materials Science and Engineering Complex to be constructed east of the current X-10 Site.

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] Over the past decade it has become increasingly clear that the need is not only for cutting-edge research but also for the close cooperation among universities, industries, and national laboratories that can rapidly carry ideas from inception to the marketplace. As a follow-on to the National Research Council MS&E study, the Office of Science and Technology Policy is drafting a national plan for MS&E to promote and to coordinate this area to meet the nation's future needs. Projections are that this plan will form the basis for a Presidential Initiative that will result in a substantive 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 collaborative research and development agreements (CRADAs) and licensing. These activities have grown rapidly and will increase even faster because

[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).

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 not only provide ORNL with a much-needed replacement and expansion of its materials R&D facilities, but it will also provide the 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 would benefit large, well-established programs but also would enhance 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 Center for Study of Advanced Materials (CSAM) for materials science and engineering has been proposed to increase the materials impact of the member universities (Fig. 4.7). The goals of the CSAM would be to develop broadly based scientific initiatives in materials science and 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

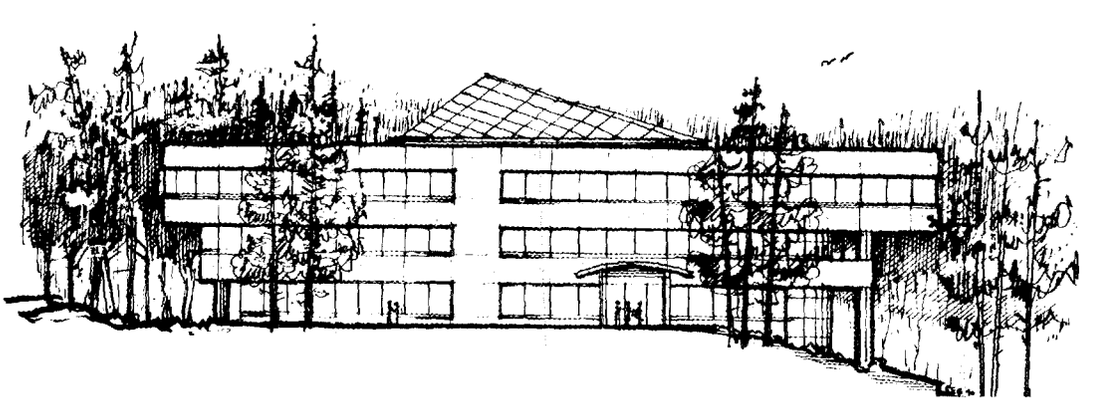


Fig. 4.7. Conceptual drawing of the Center for the Study of Advanced Materials.

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 and is now supported by DOE for faculty and graduate students from southeastern universities. Support for the CSAM is envisioned as joint funding from DOE-BES, the National Science Foundation 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 $16 million; operating costs are projected at $4 million to $5 million per year. Table 4.3 provides budget projections.

Solid State Sciences Building

The Solid State Sciences Building 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. 4.8). The 80,000-ft^2 building will provide approximately 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 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.

Center for Advanced Microstructural Analysis

The Center for Advanced Microstructural Analysis will be a national resource for the user community (Fig. 4.9). As microanalytical instrumentation becomes more sensitive, performance is limited not by the instruments themselves but by the environment in which they are situated. 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 Center for Advanced Microstructural Analysis 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

Table 4.3. Budget projections by fiscal year for the Center for Study of Advanced Materials (Millions of $)

	1992	1993	1994	1995	1996	1997
Operating expense	1.0	2.0	3.0	4.0	4.5	4.5
Capital equipment	0	2.0	0.5	0.5	0.5	0.5
Line-item construction	0	0	2.0	14.0	0	0

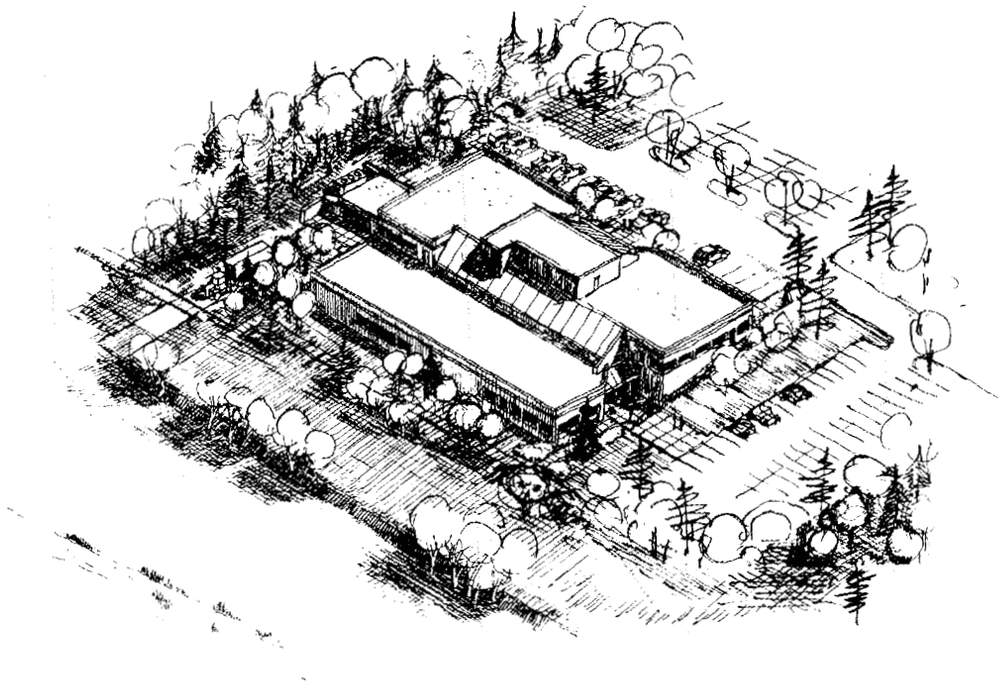


Fig. 4.8. Conceptual drawing of the Solid State Sciences Building.

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 this, 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 $37.5 million. The design will be started at the beginning of FY 1993; construction will be completed in FY 1996. Table 4.5 list budget projections.

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. 4.10). The principal ORNL divisions involved with composites are the Applied Technology Division, the

Table 4.4. Budget projections by fiscal year for the Solid State Sciences Building
($ in million—BA)

	1992	1993	1994	1995	1996	1997
Line-item construction	0	0	3.5	14.5	10.0	0

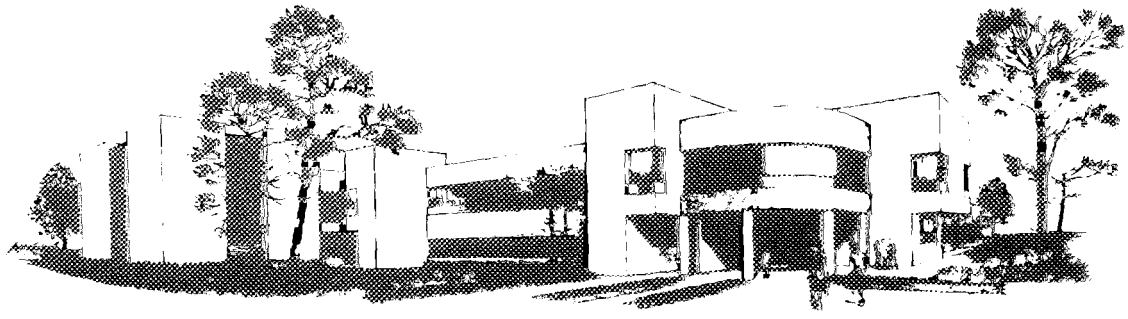


Fig. 4.9. Conceptual drawing of the Center for Advanced Microstructural Analysis.

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

	1992	1993	1994	1995	1996	1997
Capital equipment	0	0.5	1	2	1.5	1.0
Line-item construction	0	0	3	12	14.5	8.0

Engineering Technology Division, and the Metals and Ceramics Division. Other Martin Marietta 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.

The 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. Collectively, this 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.

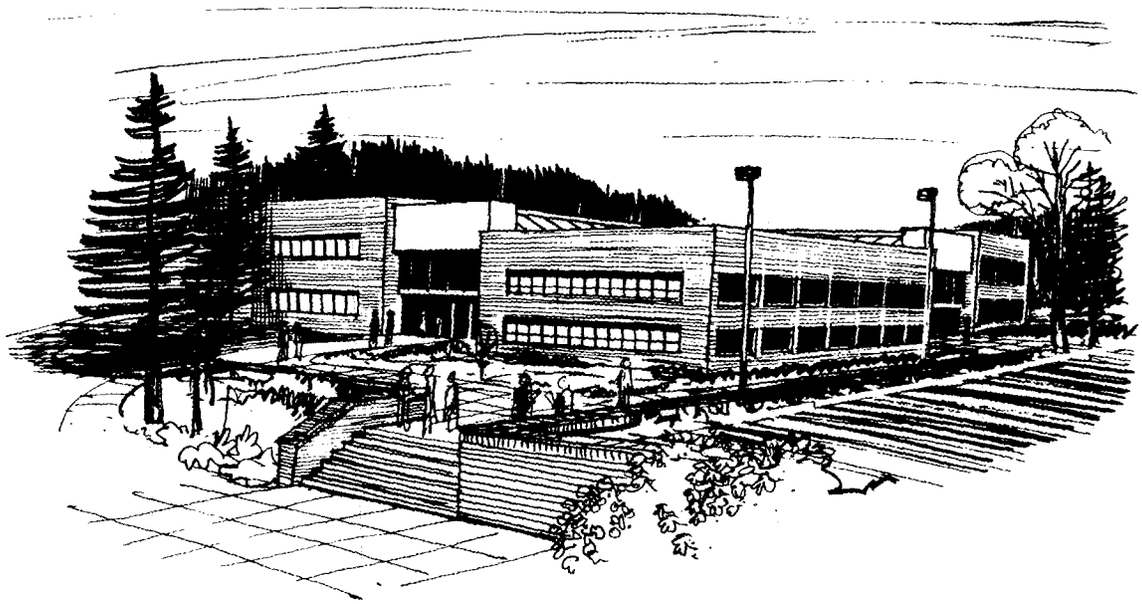


Fig. 4.10. Conceptual drawing of the Composite Materials Laboratory.

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

	1992	1993	1994	1995	1996	1997
Operating expense	6.5	8.0	10.0	11.0	12.0	13.0
Capital equipment	0.3	0.2	0.5	1.0	0.4	0.5
Total	**6.8**	**8.2**	**10.5**	**12.0**	**12.4**	**13.5**
Line-item construction	0	0	*a*	*a*	*a*	*a*

[a]To be determined.

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 facility 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, etc. The OGUI is also responsible for coordinating all CRADA agreements initiated at ORNL. The OGUI supports 10 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 2900 visits in 1990 by scientists and engineers from universities, industries, and other federal laboratories. Despite its growing importance, the OGUI is currently housed in temporary trailers. The MS&E Complex

is a logical site for construction of a permanent OGUI because the majority of ORNL user interactions are materials related. A permanent building of about 3200 ft^2 (to be constructed at a cost of about $1.2 million) is proposed as an FY 1993 GPP (Fig. 4.11).

Waste R&D Initiatives

Public awareness of environmental concerns, coupled with DOE's focusing attention on past operations, has drawn attention to substantial problems associated with waste management activities at the various DOE facilities. While technologies such as pump and treat are currently available, new techniques for stabilization, remediation, and disposal are needed. Close working relationships are necessary between basic research efforts that seek to develop long-term solutions and the applied activities that are directed toward demonstrating or modifying existing approaches. This is necessary to ensure application of the most cost-effective and technologically advanced remediation and waste management methods at DOE sites. Another important aspect of this initiative is joint laboratory-industry development of energy-efficient waste-minimization technologies for government and industrial facilities.

Applied Science

The Applied R&D component of the Waste R&D Initiatives is proposed specifically to DOE's Office of Environmental Restoration and Waste Management (EM), an organization created to deal with past, present, and future wastes at federal facilities. Located within this organization, the Office of Technology Development (OTD) is charged with maintaining an aggressive applied research, development, demonstration, testing, and evaluation program. Successful application of technology developed for the OTD will be used in remediating federal facilities; emphasis will be on the transfer of appropriate technology to the private sector. The nature and visibility of waste management issues indicate that a very aggressive

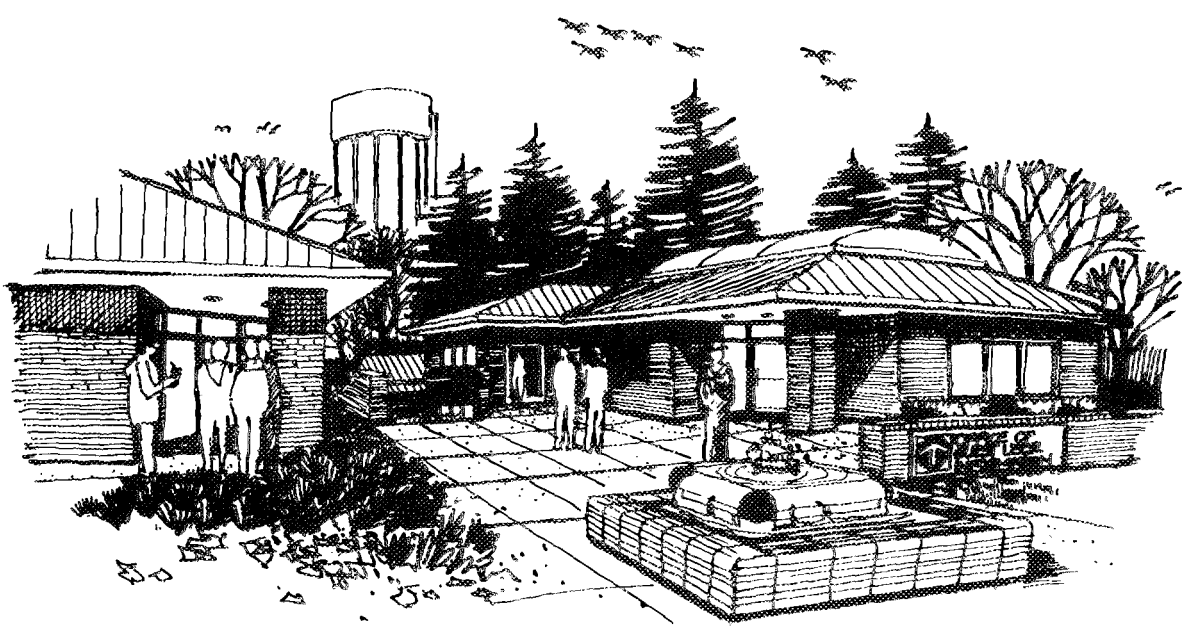


Fig. 4.11. Conceptual drawing of the Office of Guest and User Interactions.

program and growth rate are necessary and appropriate.

Because a large investment is required to remediate environmental insults at the DOE facilities, a vigorous R&D program is needed to minimize cleanup costs, to quantitatively understand the risks posed by the contaminated sites, and to help establish priorities. The purpose of this applied R&D component is threefold: research, development, and demonstration of advanced technologies that will significantly reduce the costs of environmental restoration and waste management while meeting current (and future) regulatory requirements in a manner acceptable to the public.

One component of this multifaceted program is to determine methods or to develop techniques that will identify and characterize the wastes and waste sites associated with the various DOE facility operations, particularly those within the eastern half of the United States. As part of this characterization effort, more useful tools need to be developed to respond to compliance requirements at minimal cost. These include

- modeling of hydrologic systems;
- advanced field measurement and sensing techniques;
- improved methods for data collection, analysis, management, and display;
- instrumentation to monitor contaminant behavior and response to remediation techniques using improved, less costly, analytical techniques in situ and real time; and
- field-oriented methods that allow both site and contaminant characterization with minimal cost and health and safety impact.

A second component of the applied effort involves assessment of existing waste management methods and evaluation, development, and demonstration of new potential technologies for waste treatment. Some of these potential technologies may currently be in use in other industries, but they have not been considered for applicability to waste management. These technologies also need to address all three aspects of restoration and waste management: (1) cleanup (remediation) of existing contaminated sites, (2) better techniques for managing wastes currently being generated, and (3) process modifications to minimize future waste generation. The technologies currently being evaluated and developed include

- bioremediation/biotechnology—microorganisms that can fix, degrade, detoxify, or accumulate organic and selected inorganic species in situ or in process;
- robotics—robotic systems and remote technology that can enhance environmental restoration and waste management operations by removing workers from hazardous materials, increasing speed and productivity of operations, and reducing life-cycle costs;
- in situ stabilization—waste treatment to eliminate environmental insult; and
- advanced separations technologies—waste concentration to permit more effective and efficient management.

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 in this component of the program, particularly in the demonstration phase; this will require an efficient transfer of new technologies for applications both to and from the DOE facilities.

Concern over the lack of qualified trained scientists and engineers to solve future problems has led to an increased emphasis on education at DOE. ORNL is responding to this concern by developing joint research projects with universities and historically black colleges and universities to encourage students to study in fields applicable to environmental restoration and waste management. Table 4.7 lists budget projections for OTD programs.

Waste Minimization

A forward-looking component of the Waste R&D Initiative is waste minimization, an important part of any organization's waste management program. Waste minimization strategies typically

Table 4.7. Budget projections by fiscal year for the Office of Technology Development programs ($ in millions—BA)

	1992	1993	1994	1995	1996	1997
Operating expense	14	19	21	25	28	32
Capital equipment	2	2	2	2	2	2

incorporate changes in processes, raw materials, and products, but effective waste minimization strategies must also incorporate changes in institutional attitudes and standards.

The general objective of waste minimization is to eliminate to the extent possible the volume of waste or the hazardous nature of the waste by modifying the feedstock, the waste generation process, or the character of the effluent streams. Within the DOE system, waste minimization efforts have been primarily focused on production sites that tend to have large, common operations. There is, however, an increasing awareness that smaller waste streams, such as those produced by national laboratories, may prove equally challenging and troublesome because of their diversity and number. In many organizations a program to minimize wastes proceeds in an ad hoc, piecemeal fashion that tends to focus on individual waste streams.

ORNL intends to establish itself as a DOE model facility for waste minimization. As a first step, the Laboratory-directed R&D includes a project that will develop a methodology for an advanced waste minimization expert system. Although ORNL will be used as the test case, the waste minimization evaluation methodology to be developed will be applicable to all types of DOE (and industrial or other) sites. The DOE Office of Industrial Technologies, Conservation, and Renewable Energy has initiated a new program to help improve the efficiency of industrial processes through cost-effective waste reduction. ORNL will participate in this industrial waste reduction program through CRADAs with industrial partners.

Basic Science

While some of DOE's contaminated sites can be (or because of compliance or other constraints, must be) handled 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 rapidly evolve 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;
- 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 initiative 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.

The necessity of having an initiative that focuses specifically on issues that require a relatively long lead time and that are not specifically directed at resolutions of a pressing problem is evident if the environmental restoration efforts of DOE are to be met effectively. Increased attention will be given to this need; it is an opportune time for ORNL to take advantage of its multidisciplinary expertise and experience in waste R&D in developing this area. The setting of ORNL and the functional relationship with other DOE plants in the humid eastern United States provide a unique opportunity for field-testing assorted projects involving characterization, remediation, and disposal. This initiative would involve multiple divisions within the Laboratory structure and would keep ORNL at the cutting edge of an area that is rapidly expanding. As a basic science initiative, this component of the waste R&D initiatives is specifically addressed to the Office of Energy Research. Table 4.8 lists budget projections.

Grand Challenges in Computational Science

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 (e.g., 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

Table 4.8. Budget projections by fiscal year for the Basic Science R&D component of the Waste R&D Initiatives ($ in millions—BA)

	1992	1993	1994	1995	1996	1997
Operating expense	1.8	2.8	4.5	5.5	6.3	6.3
Capital equipment	0.5	0.8	1.0	1.2	1.2	1.2

these can be brought to bear on specific applications.

To address these issues, ORNL is establishing a Center for Computational Science (CCS) to provide leadership and support for computational science activities at ORNL. Initial funding for this center is expected to be primarily through the federal High Performance Computing and Communication (HPCC) Program. The vehicle for ORNL participation in the HPCC 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; The University of Tennessee, Knoxville; the University of Wyoming; and Vanderbilt University. The partnership has submitted a proposal to DOE; funding is to start in FY 1992.

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 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 computer science research,
- a program for high-performance computing access for high school students, and
- state-of-the-art multiple instruction, multiple data systems to support the other objectives.

The PICS proposal takes advantage of unique resources at ORNL and its partner institutions to provide the combination of expert scientists and engineers with computing-intensive applications, research expertise in parallel computing, and parallel-computing hardware necessary to solve grand challenge computational problems in science and engineering.

The three grand challenges selected for initial research by the partnership are groundwater transport in environmental modeling and remediation, first principles simulation of materials properties, and quantum structure and dynamics of matter. These three problems satisfy the following basic criteria for selection:

- The problem is of fundamental importance, and its solution would be of great value to society of 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 Superconducting Supercollider (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 has one of today's fastest supercomputers in the 128-processor Intel iPSC/860, peak rated at 10 gigaflops (32-bit arithmetic) and 7.6 gigaflops (64-bit arithmetic) (Fig. 4.12). Less powerful versions of other parallel computers with fundamentally different architectures that are suitable for architectural analyses and pilot implementations for specific applications are also

Fig. 4.12. ORNL's iPSC/860 is one of today's fastest computers.

available at ORNL and its partner institutions. These computers 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 assess parallel computers at other national computer centers and research organizations.

In late FY 1991, a Kendall Square system will be acquired with interim DOE funding augmented by funds from the ORNL director's R&D fund. The partnership will then be in a position to evaluate the merit of Kendall Square systems for the problems at hand. The PICS proposal also plans for a larger high-performance system to be installed during FY 1992.

Preliminary studies of the type envisioned 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 are currently being implemented by interdisciplinary teams from the Engineering Physics and Mathematics, Metals and Ceramics, and Physics divisions of ORNL. Projects have also been initiated in climate modeling and fusion energy calculations. 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 two ORNL staff members as winners of the 1990 Gordon Bell Prize for best price:performance ratio in parallel processing. Their code computes the electronic structure of high-temperature superconductors and runs at 2.5 gigaflops on the Intel iPCS/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 more accurately predict 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 feasibly modeled. 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 "plug-in" modules 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 part 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 plan is to evaluate selected existing flow-and-transport codes and to parallelize selected codes to initiate studies on sensitivity analysis, incorporation of phenomena, optimal bioremediation, and parameterization issues. We will investigate new algorithms and the coupling of phenomena. Finally, we will design and implement a modular software package.

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), use these models to obtain fundamental understanding of materials, and use the models to aid in the design of materials. The need for powerful parallel supercomputers 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 plan of the Quantum Structure and Dynamics of Matter Grand Challenge is to develop algorithms for strongly time-dependent, strongly interacting quantum mechanical systems, to implement the algorithms on high-performance parallel computers exploiting the architecture of the computer, and to apply the codes running on parallel computers to atomic, molecular, and nuclear systems with some effort in condensed matter and high-energy physics problems.

This effort will extend time-dependent Hartree-Fock methods to laser, chemical, and surface problems and will apply quantum hydrodynamics codes to collective phenomena in nuclear and electronic matter. Both of these exploit techniques common to several branches of physics. The effort will also develop software tools with wide applicability such as a basis spline collocation and random number generators for parallel and vector machines.

From a programmatic point of view, the quantum structure and dynamics of matter effort exploits existing strong collaborations, is oriented towards major DOE programs in Basic Energy Sciences and Nuclear Physics, but complements existing activities, and is unique in focusing on time-dependent problems and in adopting an interdisciplinary approach.

The short-term objectives of this effort include research to calculate low-energy ion-surface collisions in all three space dimensions with time-dependent Hartree-Fock codes based on spline methods, to calculate the relativistic nuclear collisions using hydrodynamics codes with non-Abelian color fields coupled to the matter flow, and to benchmark some existing codes on the parallel computers.

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 supercomputer-visualization relationship is well understood at ORNL.

The plan for the visualization effort is to develop an Advanced Visualization Laboratory with significant and current equipment including equipment to support research in virtual reality. Novel and fast communication technologies will be explored 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 natural 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 PICS education effort will focus on the high school 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 expressed an interest in establishing centers for intensive research in this area. Many computing companies, including Intel Scientific Computers, Inc.; IBM; Kendall Square Research Corporation; and Ncube (as well as industrial firms interested in the Grand Challenge areas, such as Chevron and Eastman) 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 4.9. Acquisition of large computer equipment will likely be purchased under a lease-to-ownership arrangement with operating funds.

Table 4.9. Budget projections by fiscal year for the Grand Challenges in Computational Science Initiative
($ in millions—BA)

	1992	1993	1994	1995	1996	1997
Operating expense	10.0	19.5	23.0	26.5	29.0	32.0
Capital equipment	1.0	1.0	1.5	2.0	2.0	2.0

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 largest detector systems will be major development tasks that will cost several hundred million dollars. The smaller detectors will even require tens of millions of 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 the Southern Association of High-Energy Physics (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). This group is expected to produce the 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 addition to the large SDC, 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.

Until recently the L-Star (L*) detector collaboration was a major contender for the second large detector system, and ORNL had responsibility for detector component design and systems integration. The L* collaboration has now been discontinued, and discussions are currently under way to produce another detector system that will be special purpose and complementary to the SDC detector. ORNL will be heavily involved in this effort.

To coordinate all of our SSC-related activities, the Oak Ridge Detector Center (ORDC) was formed almost 2 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 will be (1) to establish the Southeast as a major force in high-energy physics; (2) to enhance cooperation for joint detector R&D between 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. 4.13); 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

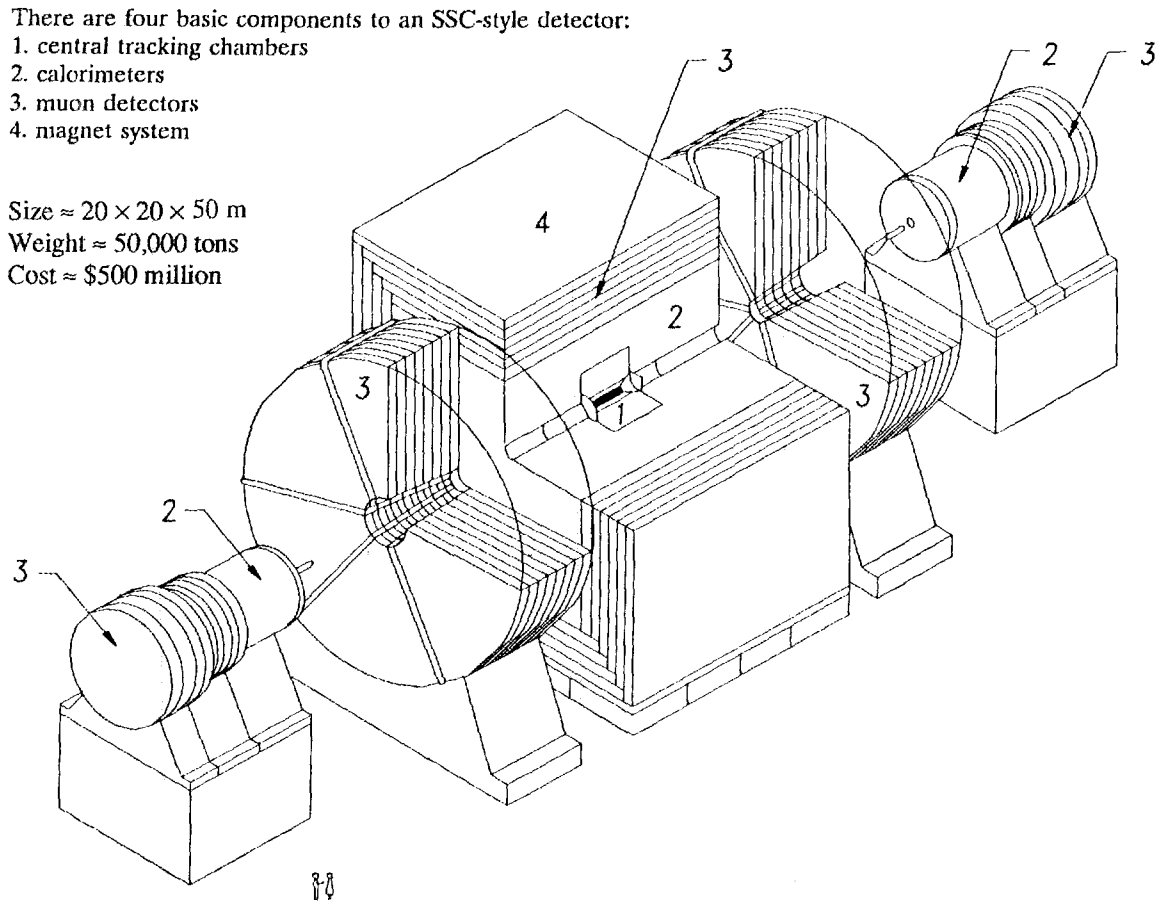


Fig. 4.13. ORNL will be involved in designing, engineering, and building detector components for the Superconducting Super Collider (SSC). This figure shows the design and scale of an SSC-type detector.

include detector simulation; radiation damage; and electrical, mechanical, and materials engineering. The funding for these research projects is currently coming either directly or indirectly from the DOE SSC Laboratory and is anticipated to increase during the next several months.

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. As part of this initiative, the Laboratory has joined the L3 collaboration at Centre European pour la Recherche Nucléaire (CERN).

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 and the High-Energy Physics Research Program to follow. The magnitude of the anticipated growth is indicated by the projected new funding (Table 4.10).

Table 4.10. Budget projections by fiscal year for the High-Energy Physics Research Program and the Oak Ridge Detector Center ($ in millions—BA)

	1992	1993	1994	1995	1996	1997
Operating expense	1.5	2.5	3.5	3.5	3.5	3.5
Capital equipment	1.0	2.5	3.5	3.5	3.5	3.5

Education Technology

The particulars continue to be debated, but on the subject of American education U.S. citizens and their leaders agree on one point: 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. And in the vital fields of science and mathematics, ORNL works with various universities, school systems, and federal agencies to provide innovative programs for some 20,000 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 work place. 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 synthesis 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 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 through a "flying carpet" or "time machine"; and

- regional teacher-training, prototypic seminars for 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 the world's computer-based resources);
- Hobbes (furnishing virtual reality capability to the K–12 classroom); and
- Madame Curious, a holographic animation functioning 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; 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 (CETI).** CETI 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).** ETI will be a joint venture initially involving The University of Tennessee, 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 (CEPO).** CEPO 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 state-wide interfacing. A number of telecommunications and computer companies have also expressed interest in providing financial and research assistance.

Targeted at grades K through 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-tech 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 4.11).

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

	1992	1993	1994	1995	1996	1997
Operating expense	5.0	10.0	15.0	15.5	16.0	17.0
Capital equipment[a]	17.0	27.0	26.0	10.0	7.5	5.0

[a]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.

Other Initiatives

The following additional initiatives are proposed under program discussions in the section "Scientific and Technical Programs."

- Office of Energy Research
  - Radioactive Beams/RMS/Gammasphere
  - Melton Valley Nuclear and Radiochemical Technology Center
  - Center for Excellence in Research Reactors
  - Advanced Photonics for Environmental Needs
  - The Liquid State of Matter
  - Subsurface Research
  - Environmental Biotechnology
  - Structural Biology
  - ORNL Genome Program
  - Global Environmental Studies
  - Direct Funding for ES&H Compliance Efforts

- Assistant Secretary for Nuclear Energy
  - Modular High-Temperature Gas-Cooled Reactor Technology Development—Direct Cycle
  - Center for Excellence in Research Reactors (See Office of Energy Research.)
  - Actinide Recycle
  - Oak Ridge Participation in Planning for the National Space Program

- Assistant Secretary for Defense Programs
  - Advanced Materials Design Methods and Manufacturing

- Assistant Secretary for Conservation and Renewable Energy
  - Energy Technologies for Developing Nation (Including Eastern Europe)
  - Center for Risk Management
  - Health Physics Instrumentation Center

5. scientific and technical programs

5. Scientific and Technical Programs

U.S. Department of Energy

Office of Energy Research

The Office of Energy Research is the largest single sponsor of research at Oak Ridge National Laboratory (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 the U.S. Department of Energy's (DOE's) Magnetic Fusion Program, the plans for which are outlined in the National Energy

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

Budget and reporting code	Major program	Fiscal year 1990	1991	1992	1993
AT	Magnetic Fusion	29.9	26.0	30.3	38.1
KA	High-Energy Physics	0.4	0.4	2.0	2.5
KB	Nuclear Physics	15.3	13.7	14.3	17.0
KC	Basic Energy Sciences	77.3	98.1	140.1	142.4
KD	Energy Research and Analysis	2.1	0.2	1.5	1.6
KG	Multiprogram Energy Laboratories Facilities Support	16.9	6.5	1.5	2.6
KP	Biological and Environmental Research	27.7	28.4	36.5	40.3
KS	Superconducting Super Collider	0.7	1.0	1.3	1.5
KT	University and Science Education	0.8	1.5	2.0	1.7
	Landlord activities[b]	9.0	0	0	85.7
Total		**180.1**	**175.8**	**229.5**	**333.4**
Percentage of total Laboratory funding—BA		35.6	34.7	32.5	39.2

[a]Includes funded operating BA, capital equipment, and 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.

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 Engineering, Computing and Telecommunications, and Oak Ridge Y-12 Plant organizations.

The goal of the U.S. 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. 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 research and development (R&D) areas, an excellent record in technology transfer to industry, and the potential of the Oak Ridge Reservation as a site for major deuterium- and tritium-burning fusion experiments.

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 achievement of reactor-level plasma, component, and system reliability and maintainability;
- the development of radiation-resistant and low-activation materials;
- the development of a site for a major deuterium-tritium facility; 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 also 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 an essentially 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 funds theory, atomic physics, and diagnostic development; the second, confinement experiments, the Burning Plasma Experiment (BPX), and some applied plasma technology; and the third, materials research, plasma technology, the International Thermonuclear Experimental Reactor (ITER) Project, and systems studies.

AT05—Applied Plasma Physics The Applied Plasma Physics subprogram at ORNL includes theoretical and computational studies for formulating, validating, and applying theoretical models of plasma behavior to toroidal confinement systems. The primary emphasis is on understanding plasma confinement and its limitations in tokamaks. Subsidiary work is undertaken for a supporting concept —the stellarator. The essential similarities of the two concepts simplify analysis, while the differences can be exploited to isolate specific physical phenomena. The most notable differences are instabilities driven by currents parallel to the magnetic field. ORNL contributions include work in the following areas:

- transport driven by instabilities (as assessed by ORNL stability models),
- effects of turbulent and direct current electric fields,
- tailoring of magnetic fields to reduce particle drift losses and lower collisional transport,
- fueling and heating techniques to adjust profiles and to control energy and particle losses, and
- direct current drive (radio frequency beams) for tokamaks.

The theoretical effort is directed toward applications that improve U.S. tokamak initiatives (i.e., the BPX, the ITER, and the Advanced Reactor Innovation and Evaluation Study). Low-aspect-ratio tokamak ideas developed at 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 U.S.S.R.

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 has been installed on the Advanced Toroidal Facility (ATF) and will begin proof-of-principle tests soon.

AT10—Confinement Systems The main focus of the Confinement Systems subprogram at ORNL has been the ATF experiment. The ATF has the flexibility to study various magnetic configurations and to contribute to the understanding of toroidal confinement. Key contributions have already been made to understanding the plasma-driven (bootstrap) current and plasma-edge turbulence (in collaboration with the University of Texas and California–San Diego). Access to the second region of stability has been achieved. The present program is studying transport and electric-field effects with the magnetic configuration varied during long pulses (Fig. 5.1). The ATF can achieve steady-state operation, and preliminary trials will be made in 1991. At the end of FY 1991, the ATF will be mothballed. A technical review of ATF should lead to restart at the end of 1993. In the meantime, ORNL confinement staff will transfer to support collaborative programs in transport studies, divertors, and fueling and heating on DIII-D at General Atomic Company and on PBX-M and the Tokamak Fusion Test Reactor (TFTR) at the Princeton Plasma Physics

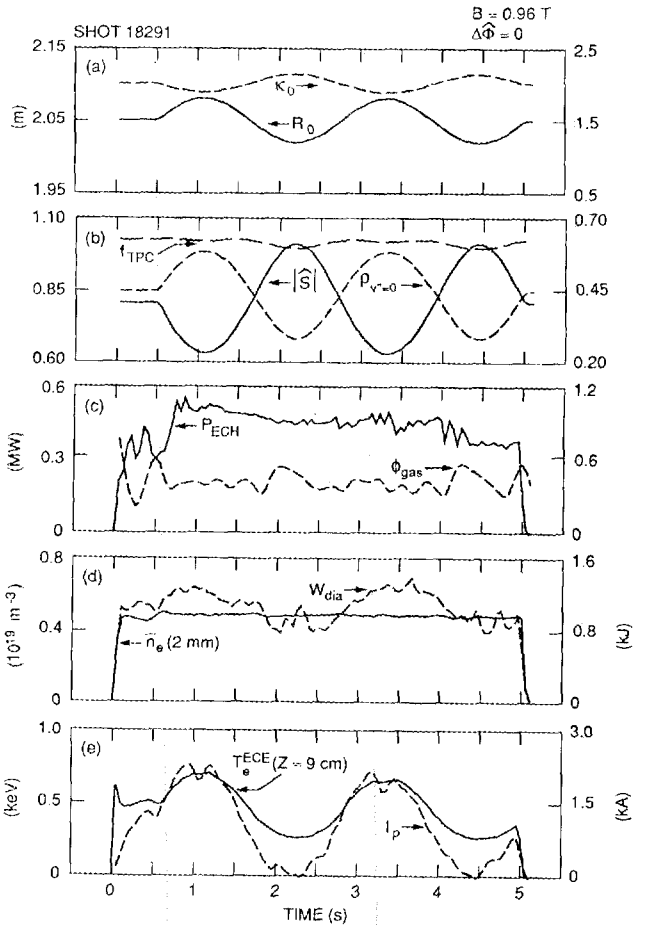


Fig. 5.1. Shear modulation experiment. Near-term enhancement: electron-cyclotron heating power modulation; longer pulse length.

Laboratory. These new programs extend existing collaborations on the Tokamak Experiment for Technically Oriented Research (Germany), the Tore Supra (France), and the ORNL–Joint European Torus (JET) (European Economic Community, Culham); on techniques for understanding and controlling the plasma boundary; on pellet fueling; and on ion-cyclotron heating (ICH) and current drive. These programs take advantage of ORNL's ability to integrate the various aspects of fusion research. Figure 5.2 shows the high-fusion gain achieved with the use of an ORNL pellet injector coupled with ICH on the JET tokamak.

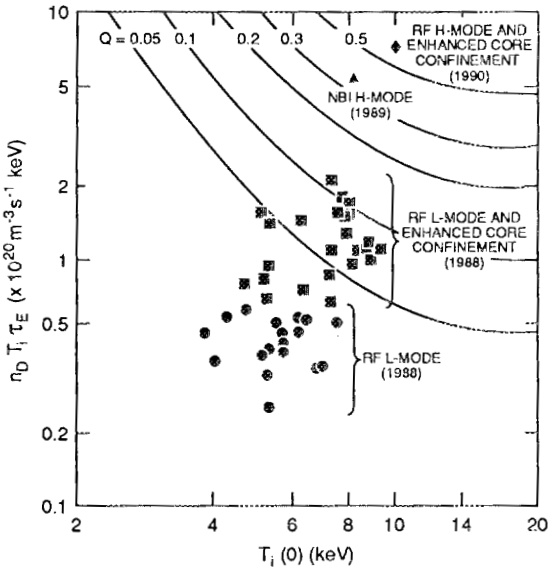


Fig. 5.2. Fusion parameters on the ORNL Joint European Torus illustrating enhanced confinement with central fueling and heating.

AT15—Development and Technology The Development and Technology subprogram at ORNL continues to make impressive contributions throughout the breadth of its work. ORNL is a major center for the development of heating systems for plasmas. In recent years this work has been directed at developing systems for heating with electromagnetic waves (commonly referred to as radio frequency systems). The ORNL Radio Frequency Test Facility is an important element in the development and test of the radio frequency launching structures. A recent advance has been the demonstration that the folded waveguide (Fig. 5.3) has superior properties to a traditional loop antenna of comparable size. Plans are under way to upgrade ion-cyclotron heating and current drive on DIII-D as part of the ORNL–General Atomic Company collaboration.

An efficient method of fueling plasmas is by the injection of pellets of solid hydrogen at high

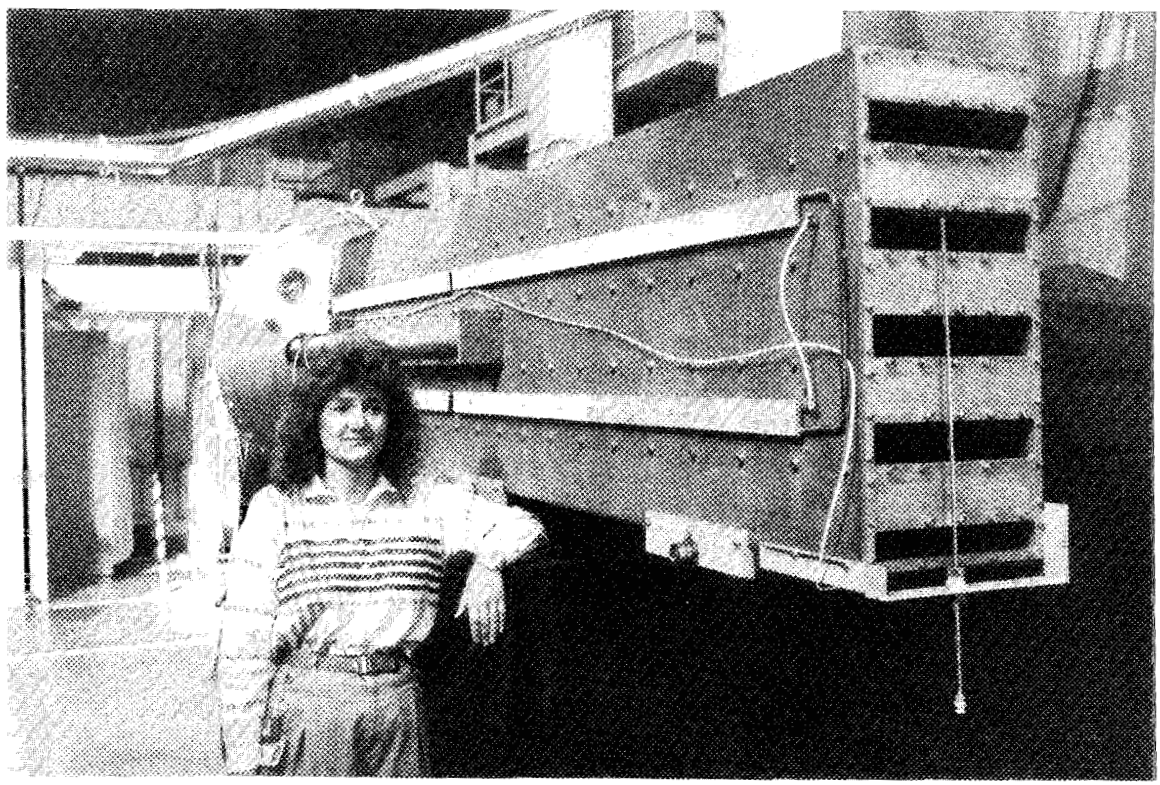


Fig. 5.3. Prototypic folded waveguide array showing the side of the launching structure that faces the plasma.

speed (> 2 km/s). The Pellet Injector Program continues to be one of ORNL's outstanding contributions to the World Fusion Program. Multiple pellet fueling has been demonstrated on Tore Supra (Fig. 5.4) using a centrifugal pellet injector. It is planned to upgrade the TFTR pellet injector for tritium compatibility and to add a 3-km/s two-stage gas gun for tritium injection. Development of two-stage gas guns (speeds of 5 km/s have been achieved with plastic pellets) and electron beam–rocket pellet accelerators continues for the BPX and the ITER.

It takes many years to develop a production capability for radically new materials, and in anticipation of fusion's needs, such development has been under way at ORNL since the 1970s. Substantial advances have been made in the development of alloys to withstand the fusion neutron environment. A major thrust of the program is to concentrate on alloys that will have

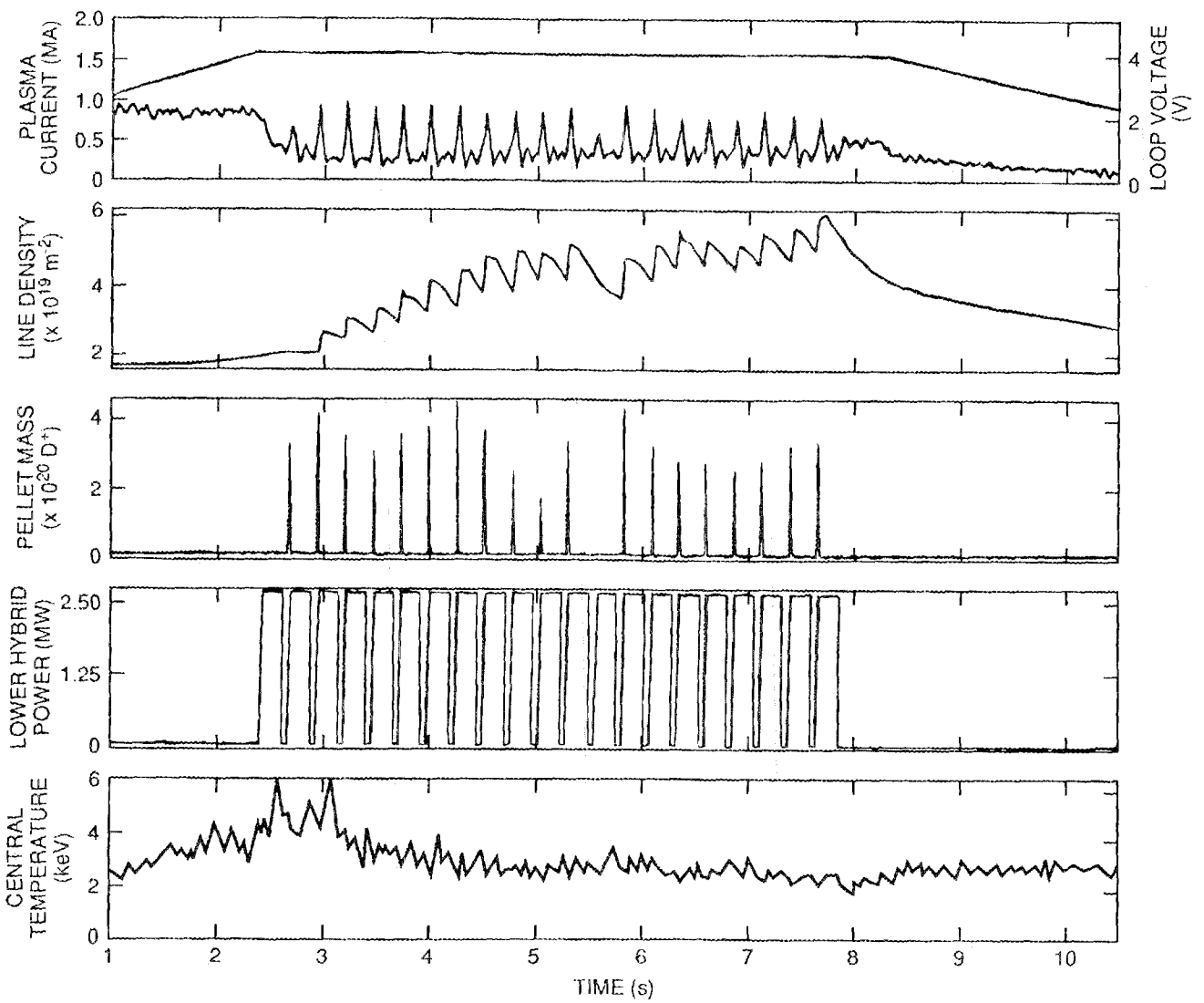


Fig. 5.4. Quasi-steady-state fueling in the Tore Supra. Up to 25 pellets injected, limited only by pulse length. I_p = 1.4 MA; B_t = 4 T. Quasi-stationary density at 4×10^{19} m^{-3}; $n_m/n_e \geq 1.5$.

low induced radioactivity. Promising austenitic and ferritic steel compositions with favorable mechanical properties have been produced. Work is also under way to resolve key material problems for the BPX and the ITER. These alloys are being tested in the High-Flux Isotope Reactor (HFIR) irradiation facility. Other irradiation experiments involving graphite and carbon-based ceramics are also under way. A multiyear collaboration with the Japan Atomic Energy Research Institute is a key part of this program.

The Advanced Systems Program has been organized as a focal point for activities related to future fusion experiments. The ORNL Fusion Engineering Design Center (FEDC) is the major engineering resource for the program. Since its formation in 1979, the FEDC has had a leading role in the design of next-generation devices. The FEDC has collaborated extensively with U.S. industries, national laboratories, and universities. The major role that ORNL and the FEDC play in the design aspects of the ITER and the BPX is illustrated by their contributions in physics, reactor design and integration, remote handling, and plasma technology systems. The FEDC also contributes to the Advanced Reactor Innovation and Evaluation Study headed by the University of California at Los Angeles.

ORNL is also applying its fusion technology expertise to a variety of nonfusion applications. Examples include the use of (1) microwaves for sintering ceramics and processing liquid wastes; (2) microwave plasmas for producing semiconductors; and (3) plasma processing for cleaning and preparing surfaces, the production of diamond coatings, and the application of magnetic expertise to advanced superconducting magnets for a variety of defense and civilian needs. The long-term goals of the ORNL Fusion Energy Program are

- to ensure the effectiveness of multilaboratory collaborations;
- to continue the ATF Program;
- to support spherical torus research in the world program;
- to develop an advanced toroidal device for construction at ORNL;
- to continue a broad technology program with emphasis on heating, current drive, fueling, materials, and remote handling;
- to be a major participant in the BPX and the ITER; and
- to maintain a strong position for Oak Ridge as the site for a major deuterium- and tritium-burning plasma facility and to obtain such a facility.

Continued Operation of the ATF

The ATF, the world's largest stellarator experiment, has a facility value of over $100 million. It was designed as a flexible research facility to support and to complement the mainline tokamak in developing an understanding of fundamental toroidal physics and an improved toroidal concept. Since start of operation in 1988, the ATF has already made significant contributions to this understanding. In addition, a stellarator has the potential for steady-state operation without dangerous disruptions or the need to drive large plasma currents (these can be serious limitations to a tokamak fusion reactor). The goals of continued operation of the ATF would be threefold:

- study fundamental toroidal physics at a high power level (6 MW) for long pulses ($\lesssim$30s);
- contribute to the development of stellarators and stellarator features as a cost-effective part of the broader world stellarator program; and
- demonstrate disruption-free, steady-state operation at high-edge power densities and at high beta (i.e., test divertor and plasma technology components and test divertor concepts including an axisymmetric poloidal divertor).

The resulting ATF Program would proceed in stages:

- tests of fundamental physics and steady-state operation at low power $\lesssim$0.4 MW) during FY 1991,
- completion and installation of long-pulse ($\lesssim$30s)

heating systems to deliver 4–6 MW to the plasma and design of divertor structures during FY 1992–FY 1993,
- restart of operation at the end of FY 1993, and
- buildup of steady-state heating and power-handling capability from FY 1994 onwards (this staging will allow optimization through experience as the power and pulse length capabilities are increased).

Fusion Energy Division Programmatic Issue A major programmatic issue for the Fusion Energy Division is the closing in FY 1992 of the ATF Program and the mothballing of the ATF. The ATF has a unique capability in the world program for support of the mainline tokamak both in providing a better understanding of fundamental toroidal science and in developing routes to overcoming the problems of the tokamak—disruptions and attaining steady-state operation. In addition, the ATF is the only major experiment in the United States capable of operating in steady state. It can provide, cost-effectively, information on the physics performance of steady-state divertors as well as on divertor and plasma technology components. The ATF Program, a major element in ORNL's role as a collaborative organization, has an outstanding capability for integration of the various facets of magnetic fusion research. We propose that a technical review be held of the ATF Program in CY 1991 emphasizing the need for continuation of the program and restart in late FY 1993.

KA—High-Energy Physics

The High-Energy Physics Program is anticipated to grow significantly in the future as a result of activity related to the national Superconducting Super Collider (SSC) Project. In addition to existing activity in radiation-shielding design, a significant increase in effort associated with the joint experimental high-energy physics program between The University of Tennessee (UT) and ORNL 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.

KB—Nuclear Physics

The Nuclear Physics Program emphasizes basic nuclear physics research, both experimental and theoretical, and operation of two major user facilities: the Holifield Heavy Ion Research Facility (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 1990 and 1991 have proved to be a period of special challenge as the HHIRF experienced an approximately 28% operating budget reduction. This decrease, along with increased Laboratory overhead rates, has resulted in a significant reduction (i.e., 30%) in operating hours, has prevented use of the Oak Ridge Isochronous Cyclotron (ORIC) as an energy booster, and has slowed further development of the facility. Coupled with an increase in demand for facility beam time, these changes have resulted in a significant reduction both in the number of proposed experiments that may be performed and in the valuable training provided to graduate students who perform their research at this facility.

The response to this budget problem has focused on two areas: maintenance of the high quality of the beam time that can be made available for research and work on initiatives that will improve the future competitive position of the facility. The most important of these new projects is development of a recoil mass spectrometer and development of energetic beams of radioactive nuclei. The recoil mass spectrometer is a $2.2-million device jointly funded by DOE, ORNL, Oak Ridge Associated Universities, Idaho National Engineering Laboratory, Vanderbilt

University, the state of Tennessee, UT, and several other universities. This device has unmatched capabilities for observing very weakly produced isotopic species. Because of this ability, the recoil mass spectrometer is an excellent complementary device to the proposed radioactive beam capability.

While centered on the HHIRF, the low- and medium-energy research program also includes a broad program 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; considerable overlap occurs between each area. 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 the HHIRF. 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 using major research equipment developed by the research staff. Nuclear structure research uses a close-packed array 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 13 experiments since it became operational in 1990. Much of the study of reaction dynamics is carried out using a multielement detector system (HILI) 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 Conseil Européen pour Recherche Nucléaire (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 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 (BNL), however, are expected to lead to a relatively baryon-free plasma dominated by created particles. ORNL has the leadership role on one of the major detectors, the dimuon detector, under consideration for the RHIC. Because of their penetration properties, leptons are also considered to be excellent probes of the quark-gluon plasma. A certain fraction of muon 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 design of the RHIC dimuon experiment. A technical proposal is being prepared for the RHIC dimuon detector.

KB03—Nuclear Theory Program The Nuclear Theory Program centers on studies of

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 at the HHIRF (Fig. 5.5).

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 Lawrence Berkeley Laboratory (LBL). After 18 months of operation, a mandated move of Gammasphere will occur. As part of this arrangement, 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. We have now submitted a formal proposal for this effort. 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 cyclotron 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 would produce radioactive isotopes (via fusion reactions in thick targets) that would then be prepared for reacceleration in the tandem

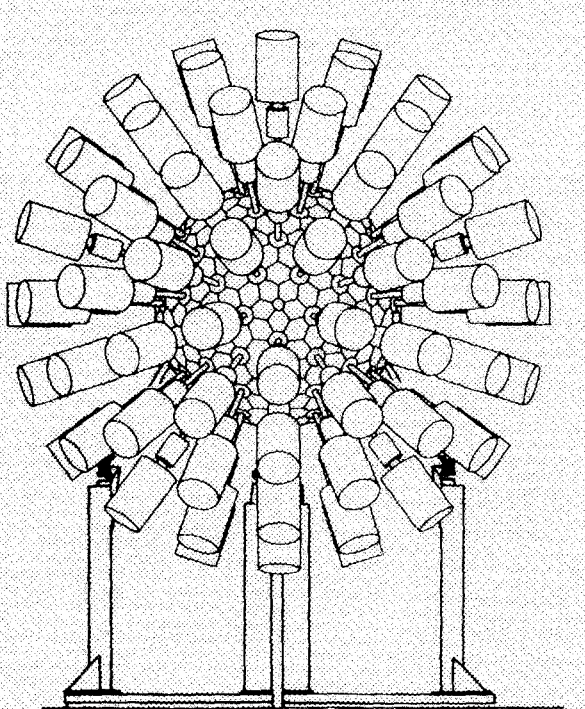


Fig. 5.5. Sketch of the Gammasphere detector system.

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, 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 somewhat deferred. The first priority is to ensure that the HHIRF remains in operation. If this is successful, a major initiative will be the development of a radioactive ion beam capability. The acquisition of the new recoil mass spectrometer (intended to complement Gammasphere) will continue, and it will become a crucial experimental device to exploit the radioactive beam capability. If we are successful with the development of radioactive beams, we feel confident that this capability, along with the presence of the recoil mass spectrometer, will make the HHIRF the preferred site for Gammasphere at the time of the first move. Table 5.2 presents budget projections.

Table 5.2. Budget projections by fiscal year for development of radioactive ion beam capability at the Holifield Heavy Ion Research Facility ($ in millions—BA)

	1992	1993	1994	1995	1996	1997
Operating expense	0.3	0.3	0.5	0.5	0.5	0.5
Capital equipment	2.2	2.8				

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 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 approximately 80 MeV. Funding is also provided for related activities including the evaluation of neutron cross sections as well as nuclear model development.

Initiatives include replacement of the existing ORELA data-acquisition computer system and utilization of a barium fluoride photon multiplicity

detector system for capture and fission cross-section measurements in the electron volt neutron energy range. In connection with the DOE program of research pertinent to environmental restoration and waste management, the nuclear data base for actinides will be reviewed, and additional neutron measurements at ORELA will be planned as appropriate. The usefulness of neutron transmission cross-section measurements will be investigated as quantitative indicators of the presence of specific nuclides in intensely radioactive samples.

KB04—Nuclear Physics Program 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 HHIRF, 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 Program supports a broad spectrum of research in the physical sciences. The two largest subprograms are Materials Sciences (KC02) and Chemical Sciences (KC03). Several key issues face these subprograms including a decision on shutdown or restart of the Bulk Shielding Reactor (BSR), development of the Advanced Neutron Source (ANS) (see "Summary of Major Initiatives"), revival of the HFIR-based neutron-scattering and irradiation programs, and increased efficiency and effectiveness in user interactions.

KC02—Materials Sciences The Materials Sciences Program supports fundamental materials R&D including neutron scattering; superconductivity; ion-beam, laser, and plasma processing; synthesis and characterization of new materials; high-temperature materials; ceramic 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, the Shared Research Equipment Program, the National Center for Small-Angle Scattering Research, and the Neutron Scattering Facility at the HFIR. Two of the Laboratory's initiatives are in the materials sciences: the ANS and the Materials Science and Engineering 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.

The metallurgy and ceramics program provides scientific leadership and a fundamental basis for the development of innovative materials. The research involves all aspects of the materials cycle: fabrication, processing, characterization, and the development of models. The program includes a wide range of high-performance materials: high-temperature alloy development, structural ceramics, and radiation-resistant materials. The focus is on application and development of advanced characterization tools including analytical electron microscopy, X-ray techniques (including synchrotron probes), atom probe field ion microscopy, mechanical properties microprobe, and ion beam techniques. Processing science research includes development of fabrication and joining techniques for advanced intermetallic alloys, ceramics, and composite structures. Ion implantation is used to study defect interactions and radiation effects and to modify surface-related properties of ceramics. The welding science program serves as the coordinator for the national Basic Energy Sciences Welding Program. A strong state-of-the-art first principles theory effort underpins all aspects of the program.

Increased program emphasis is planned in three areas: research to understand the effects of neutron irradiation environments on materials, development and processing of high-temperature ceramic materials, and utilization of the multielement-imaging atom probe. This probe will allow three-dimensional mapping of the position and elemental identity of the atomic constituents of conducting materials. For the ceramics program, expansion of the processing and characterization aspects of the

research are planned; future programmatic directions include in situ scanning electron microscope studies of fracture in ceramic composites and program expansion into nonoxide ceramic systems (e.g., silicon nitride). Increased funding will help to re-establish a world-class radiation effects program that includes extensive neutron irradiation studies. The cost of research involving reactor experiments and evaluation of radioactive materials has escalated dramatically. Environmental, safety, and health issues are especially important in such studies.

New directions in intermetallics research include the incorporation of experimental electron diffraction studies to determine charge density distributions. These experimental results will be compared with first principles calculations of atomic bonding. The surfaces and interfaces task has begun redirection to incorporate research on the application of the mechanical properties microprobe for the evaluation of structural materials, thin films, and coatings. Scheduled for completion late in FY 1991, the high-temperature mechanical properties microprobe will be capable of evaluations for specimen temperatures up to ~ 1000°C.

Long-term research directions include the development of an X-ray microprobe for the Advanced Photon Source at Argonne National Laboratory (ANL). For studies of grain boundaries, interfaces, precipitates, and similar structures, this microprobe would allow unprecedentedly low levels of detection for impurity identification and mapping. The instrument would be jointly designed and operated by ORNL, LBL, and Lawrence Livermore National Laboratory (LLNL).

The chemistry of advanced inorganic materials is a significant research area in which control of composition, purity, and morphology is emphasized in chemical synthesis. Tailored inorganic and organometallic precursor compounds and polymers are being developed whose pyrolysis and/or photolysis 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 topochemically 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, scanning-tunneling and atomic-force microscopy, and molecular dynamics simulations. Used in combination, these are revealing often unexpected structural and dynamic features, particularly in the semirigid parts of polymer systems. This program benefits from the

presence of an ORNL-UTK Distinguished Scientist.

The neutron-scattering program focuses on the structure and dynamics of condensed-matter systems. The neutron-scattering user program at the HFIR has recovered quickly with regular operation of the reactor and is expanding. New instruments installed at the HFIR during the shutdown are contributing to the research program. A request has been made for line-item funding of a project to provide a more extensive instrumentation upgrade starting in FY 1993 (Table 5.3). The project will increase the scientific value of the HFIR with a new guide hall and four new instruments designed for transfer to the ANS (see the "Summary of Major Initiatives" section). The following improvements are included in this project: (1) replacement of existing triple-axis spectrometer with a redesigned instrument, (2) improvement of the high-resolution powder diffractometer, (3) installation of a neutron guide system and the addition of a guide hall to provide more experimental space, (4) addition of a second small-angle neutron-scattering instrument, (5) installation of a neutron reflectometer, (6) installation of a residual stress diffractometer, and (7) design and construction of improved neutron-imaging systems.

Another area expected to grow steadily is the development of advanced processing techniques and studies of new materials systems. The advanced processing programs at ORNL emphasize the development of new thin-film materials and processing technologies using state-of-the-art surface modification and characterization techniques. Facilities are available for ion implantation, ion-beam deposition, laser-photochemical-vapor deposition, laser and microwave processing, solar-cell fabrication, plasma processing [i.e., glow discharge, radio frequency, electron-cyclotron resonance (ECR)], and microanalytical and electrical characterization. Active research areas in processing include

- fundamental studies of ion implantation in materials (i.e., buried insulating layers, million electron volt implantation, damage and annealing studies, dopant activation, and ion-beam mixing),
- ion-beam deposition of heterostructures and epitaxial films,
- laser processing of high-efficiency silicon solar cells,
- fundamental studies of laser-solid interactions and laser-deposited films,
- studies of high-speed epitaxial growth using supersonic molecular beams,
- laser ablation deposition of high-temperature superconductors and other materials,
- development of microionic materials and thin-film batteries,
- development of ECR plasma processing for growth of new thin-film materials, and
- development of microwave sintering for ceramic processing.

The research involves silicon- and germanium-based materials (including oxides and silicides), III-V and II-VI compounds, superconductors, optical materials, ceramics, and novel electronic materials such as diamond. The research is carried out in collaboration with more than 50 scientists from industries and universities, many of whom perform research at ORNL facilities such as the accelerators and lasers at the Surface Modification

Table 5.3. Budget projections by fiscal year for High Flux Isotope Reactor instrumentation upgrade
($ in millions—BA)

	1992	1993	1994	1995	1996	1997
Total funding	0	1.4	4.5	5.2	1.6	0

and Characterization Collaborative Research Center. A major thrust in the materials sciences at ORNL is high-temperature superconductor R&D.

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 ECR 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).

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 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,

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

	1990	1991	1992
Total funding	150	400	100

and waste isolation. Basic chemistry studies of the actinides and transactinides emphasize the elements (i.e., 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 multi-Laboratory initiative to establish a beamline at the Advanced Light Source (LBL) 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 basic energy science 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 Site.

ORNL conducts fundamental research in analytical concepts and methodologies such as

- 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 nuclear magnetic resonance techniques to chemically modified coals and the use of surface-immobilized compounds to simulate diffusional restrictions during thermal 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 metalized 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. Related research is focused on improving mass transfer in liquid-liquid processes through the use of high-intensity electric fields; emphasis is placed on understanding the underlying hydrodynamical interactions that lead to augmented performance through computation and experiment.

Additional thrusts 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, for example.

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 in aqueous solutions and sorbed on 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.

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 [i.e., the Hostile Environment Robotic Machine Intelligence Experiment Series (HERMIES)] using the small HERMIES-IIB test bed and the recently constructed HERMIES-III that 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 new waste R&D initiatives (see "Summary of Major Initiatives") mentions briefly the role that artificial intelligence and robotics might play in this multidisciplinary effort. CESAR is uniquely positioned to contribute to this initiative because of

New Initiative—Melton Valley Nuclear and Radiochemical Technology Center

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

Careful planning and development of a comprehensive center would optimize the value of large capital investments already planned in Melton Valley and minimize the additional investments needed to sustain 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 Office of Energy Research (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 and decommissioning 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 the 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 for DOE-ER and the DOE Office of Nuclear Energy (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 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 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 (i.e., two full-time-equivalent 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 (e.g., 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 presents 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 the 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 could greatly expand educational opportunities for students and for professional staff members of national laboratories, private companies, and governmental agencies. The CERR could 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 5.5 provides budget projections for the ORNL CERR. They are also included in the ORNL April 1991 budget submission summarized in the "Resource Projections" section (Table 10.5).

Table 5.5. Budget projections by fiscal year for ORNL's Center for Excellence in Research Reactors ($ in thousands—BA)

	1992	1993	1994	1995	1996	1997
Total funding	315	345	360	375	395	415

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 that may start in FY 1992.

In the Geosciences Program fundamental information is sought on the 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. Application of a unique ion-microprobe capability to isotope distribution studies in mineral assemblages has begun.

KC05—Advanced Energy Projects The Advanced Energy Projects Program supports exploratory research at moderate levels—typically for 3-year durations. Initiatives include projects addressing synthesis of advanced ceramic materials and waste-paper conversion to chemicals.

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 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 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 the "Summary of Major Initiatives" section). The expertise developed in the Applied Mathematical Sciences Program will be one of the key foundations for developing this initiative.

Computer Hardware, Advanced Mathematics, and Model Physics (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 and Analysis

ORNL supports the Office of Energy Research 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 1991 ORNL examined key issues associated with the effects of acidic deposition, photovoltaics, radon, and radiobiology. Future technical and analytic support for assessments of programs will be provided as requested. ORNL can also provide support for global climate change issues.

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, lab, and shop buildings housing administrative and Laboratory-wide support functions, utility systems, roads, etc., that relate to many programs. Line-item construction projects are those with a total estimated cost of $1.2 million or above.

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, 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 (NERP) and the Bioprocessing Research Facility. Users of these facilities include staff members of national laboratories and industry 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, 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 are the cornerstone of radiation protection and also 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 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 of 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.

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. These procedures include adding 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 analyte 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.

We have produced a variety of deoxyribose nucleic acid (DNA) adducts by incubating calf thymus DNA with the appropriate polyaromatic epoxides in vitro. Four different polynuclear aromatic hydrocarbon (PNA) compounds [i.e., benz(a)anthracene, dibenz(a,c)anthracene, benzo(a)pyrene, and methylcholanthrene] were used to produce the adducts. Subsequently, the level of addiction for the various PNAs (i.e., PNA residue per unit of base pairs of DNA) was determined using fluorescence to quantify the PNA (hydrolyzed from the DNA by acid) and ultraviolet absorbance to quantify the DNA adducts (i.e., nonhydrolyzed, bound to DNA). The synchronous fluorescence technique developed under this activity provided excellent selectivity in identifying the PNAs bound to DNA. Limits of detection by this technique are currently in the range of 1 PNA adduct per 105 to 107 base pairs, and research is under way to extend the detection sensitivity to a lower level of adducts.

ORNL researchers have international recognition in neutron dosimetry. Annual international personnel intercomparison dosimetry studies at the Radiation Calibration Laboratory (RADCAL) and Health Physics Research Reactor have been a major focus of technology transfer. RADCAL has been outfitted with radiation sources configured to deliver precise doses at specified locations. Although the major emphasis of research may be on personnel radiation dosimetry, the facility will be available for dose-effect test irradiations of small experimental animals. It is planned that RADCAL will become involved not only with personnel dosimetry and radiobiology research activities but also with national dosimeter test programs, teaching and training activities, and expanded dosimetry intercomparison studies.

A broad-based research program in the Health and Safety Research Division 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

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 (i.e., 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 (Table 5.6). Furthermore, photonics devices are becoming more compact, field-hardened, and in the case of lasers, capable of remote application.

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 ORNL's Environmental Sciences Division. 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 (i.e., chemistry, physics, and environmental science) as well as interdivisional in its contribution to solving urgent national problems.

Table 5.6. Budget projections by fiscal year for Advanced Photonics for Environmental Needs Initiative ($ in millions—BA)

	1992	1993	1994	1995	1996	1997
Total funding	0.6	0.7	0.8	1.0	1.0	1.0

Continuing Initiative—The Liquid State of Matter

In terms of fundamental knowledge, liquid is the least explored and least understood state of matter, yet liquid state interactions underlie a wide variety of basic research and applied technologies. Such interactions are of crucial importance in fields as diverse as particle detectors, chemical processes, pollutant transport, and radiation effects in biological cells. Our Liquid State of Matter Initiative will focus on the problem of achieving deep understanding of fundamental liquid-phase behavior, the goal of which is predicting new phenomena and improving existing technologies (Table 5.7).

Research areas will include (1) studies of the optical and electrical properties of liquids (especially transient phenomena using fast laser and electron probes) having application, for instance, to improvements of liquid particle detectors; (2) elucidation of the relation of liquid properties to those of gases and isolated atoms and molecules via studies of gases under extreme pressures and of atomic and

Table 5.7. Budget projections by fiscal year for the Liquid State of Matter Initiative ($ in thousands—BA)

	1992	1993	1994	1995	1996	1997
Total funding	500	560	630	700	800	900

molecular clusters (important for understanding the transport of pollutants and nutrients in the environment); and (3) studies of the transport of radiation and radiogenic products in the structured water around DNA in a cell (relevant to models of radiation damage and to solving the problem of low-dose effects).

quantifying several aspects of atmosphere/biosphere exchange that are likely to be 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 being addressed include testing methods for measuring biogenic emissions, the sensitivity of global trace-metal cycles to climate change, and development of models for scaling up surface exchange rates from point measurements. 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 (i.e., ^{7}Be, ^{35}S, and ^{210}Pb), anthropogenic radionuclides (i.e., ^{137}Cs, ^{239}Pu, and ^{240}Pu), and stable isotopes (i.e., ^{13}C and ^{18}O) to trace and to quantify the dispersal and fate of energy-related materials 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 and between continental shelf and slope. 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. To study the relevant mechanisms pertaining to houses and geology in the southern Appalachians, the Health and Safety Research Division receives DOE Office of Health and Environmental Assessment (OHER) funding at $120,000 per annum. These basic studies are designed to understand climatic, seasonal, and spatial fluctuations in indoor levels of radon and to conduct successful mitigation. In FY 1989 the

Radon Program expanded to include planning, data management, and quality assurance and quality control for the evaluation of radon problems at U.S. Naval facilities worldwide. The key components are screening and assessment measurements, quick-response verification of high radon levels by a "swat team," and mitigation training. The program, administered by the Airborne Hazardous Materials component of the Hazardous Waste Remedial Action Program (HAZWRAP), is drawing in other agencies including the U.S. Air Force and the U.S. Postal Service; funding exceeds $1 million for FY 1991.

Ecosystem Function and Response Our research on the physiological ecology of terrestrial vegetation is an integral component of the Walker Branch Watershed Project. 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. 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. Major planned activities include large-scale experiments to investigate the effects of climate change on critical ecosystem process and on ecosystem response to energy-related contaminants.

Research on vegetation response to air pollution stress (particularly O_3, S_x, NO_x, 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 NERP 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 overall DOE Waste Management 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 data-management systems associated with the 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 NERP 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 NERP. 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 NERP meetings, and administratively to manage the 5008 hectares and to monitor activities.

As is noted in the "Contributions to Economic Competitiveness" section (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 NERP 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 deer hunt planning and administration, heron rookery monitoring, rare plant surveys, a wetlands inventory, herbarium development, and turkey and small mammal population studies. Most of these activities were supported by the state wildlife agency. More theoretically based research funded by non-NERP DOE, Electric Power Research Institute (EPRI), and U.S. Environmental Protection Agency (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 on small portions of the park.

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 pattern. New emphasis will be placed on testing and on validation of theory and models through the use of field and remote-sensing

Continuing Initiative—Subsurface 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. 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 5.8). 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.

Table 5.8. Budget projections by fiscal year for the Subsurface Research Initiative ($ in millions—BA)

	1992	1993	1994	1995	1996	1997
Operating expense	3.3	3.7	4.3	5.0	5.3	5.5
Capital equipment	0.7	0.8	0.9	1.0	1.0	1.0

Continuing Initiative—Environmental Biotechnology

Environmental Biotechnology is a multidisciplinary scientific area that offers the opportunity for combining existing expertise to develop and to apply new approaches for characterizing and correcting environmental disturbances (such as waste remediation). The DOE Subsurface Science Program has provided support for basic research related to microbial processes for the past several years, and it serves as an impetus for several components of this initiative. Basic research on contributions from molecular biology will include identification of genetic loci in microbial systems demonstrating biodegradation activity including mechanisms of expression, gene enhancement, and biochemical reaction processes. Research in toxicology is directed toward development and refinement of more cost-effective tests for identifying and prioritizing contaminants requiring removal or treatment. Biological monitoring continues to be a major focus of this area. Studies are ongoing at all three Oak Ridge facilities and at Paducah and Portsmouth. Through comparison of data gathered in these studies with results of remediation activities that have already taken place, efficacy of various cleanup activities can be determined. Utilizing R&D developments in applied waste technology is affected by policy analyses that establish federal guidelines of acceptability for biotechnological advances. These technologies will also be available for transfer to other DOE facilities. ORNL expertise in social sciences and economics will be used in conjunction with R&D advances to contribute to the decision-making process. Methods that enable early detection of environmental health problems are needed. We will continue to work closely with the EPA in the Environmental Monitoring and Assessment Program as we continue to develop our own suite of indicators.

The utility of aquatic biomarkers for assessing environmental health and recovery of receiving systems will continue to be evaluated and expanded. Research evaluating plants as biomarkers has been undertaken. Development of microbial markers and gene probes is proceeding with organic and trace metal contaminants at waste sites. Efforts in bioremediation focus on developing an understanding of the environmental processes affecting rates of contaminant degradation and/or mobilization. Research is directed at recalcitrant organics and mixed waste types. Testing of available bioreactors and construction of new reactors will enable rapid application of existing technologies. Modification of these environments in bioreactors, as well as in situ, will enable application of these techniques to DOE field sites. We anticipate that increased efforts in environmental biotechnology will be applied to DOE's immediate problems, and expansion of these activities in the basic research plan supporting environmental restoration is required.

data available from the NERPs and through collaboration with other agencies (e.g., the National Park Service and the EPA's Environmental Monitoring and Assessment Program).

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 is given to interactions in the liquid including 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. ORNL proposes that the theme of molecular and mammalian genetics, a unique national resource and central to the DOE mission, be recognized as a major initiative and that strategic plans be developed for expansion.

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. A program in targeted mutagenesis that is being developed is expected to add to the capabilities for functional analysis of genes.

Molecular, as well as 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. The program, in addition, 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.

Among recent accomplishments of the mammalian genetics program are the following: (1) A 10-megabase region of Chromosome 7 has been characterized in great detail by mapping numerous anonymous DNA clones as well as newly induced point mutations to a set of nested deletions. (2) Evidence has been obtained suggesting that the mechanism responsible for certain congenital anomalies may be the disruption of transcriptional signals by chemical exposure of very early embryos. (3) Through exploitation of a complex radiation-induced chromosome rearrangement, molecular entry has been gained to the developmentally important *agouti* locus. (4) Mutation at a sex-linked locus has been found to interfere with the thymic education of lymphocytes.

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 (i.e., 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; epidermal growth factor (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 the 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 the EGF, the receptor undergoes autophosphorylation on tyrosine residues by its intrinsic protein kinase activity; this, in turn, phosphorylates exogenous substrates. This 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 the 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.
- Both agonists and antagonists of human EGF have been designed. The latter offer potential as antitumor agents; the former may be super growth promoters having clinical application in wound healing.
- 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 interleukin-3 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—Structural Biology

An interdivisional (i.e., Biology, Health and Safety Research, and Solid State divisions) effort is intended to develop support for structural biology through OHER. A core proposal that includes biological applications of small-angle neutron scattering, small-angle X-ray scattering, neutron crystallography, X-ray crystallography, and nuclear magnetic resonance is now under review by OHER. Currently, crystallographic studies of nucleosomes (Fig. 5.6), the building block of chromatin, are partially funded by OHER. Nucleosomes, reconstituted from a cloned DNA restriction fragment, have been crystallized in a form suitable for high-resolution analysis. Other crystallographic projects would entail three-dimensional structure determination of human EGF and mutant analogs designed by ORNL's Protein Engineering Program as well as a human DNA repair protein that removes alkylation lesions.

Biological small-angle neutron and X-ray scattering research was initially funded as a component of the National Center for Small-Angle Scattering Research [supported by the National Science Foundation (NSF)]. Because of the HFIR shutdown, the NSF withdrew its funds, and restoration is unlikely. The restart of the HFIR compels the establishment of core support from OHER to maintain structural biology research at these national resource facilities and to continue an ORNL program as the basis for developing structural biology programs at the ANS (Table 5.9). OHER funding is needed for three on-line scattering instruments (~ $5 million), equipment for a biological sample-preparation

laboratory ($1 million), and a multipurpose-(deuterium)-labeling laboratory ($1 million) to ensure world-class facilities to users from the biology community.

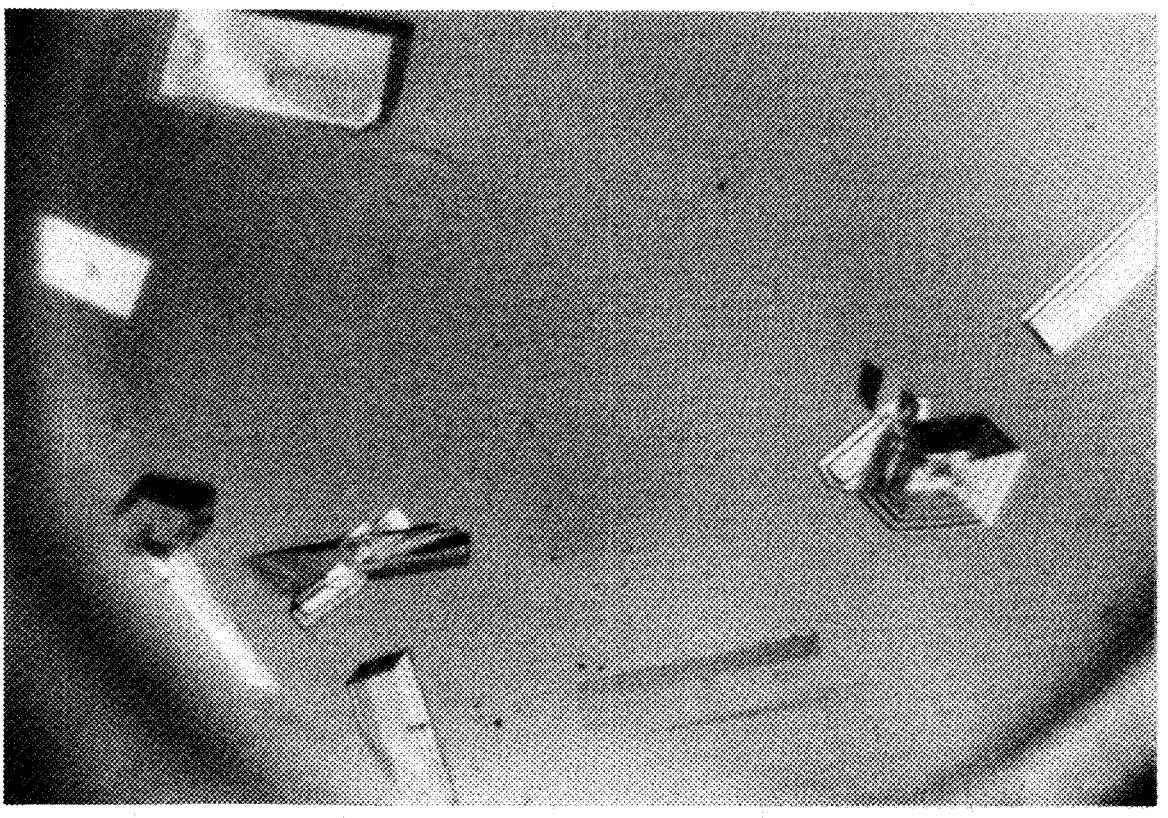


Fig. 5.6. Photomicrograph of nucleosome crystals containing human α-satellite-defined sequence dioxyribose nucleic acid and purified histones. The crystals are birefringent, display sharp, well-formed edges, and show very clean crystal faces. The largest crystal has dimensions of 2.0 × 5 0.75 × 5 0.15 mm. Experiments that will lead to a high-resolution crystal structure of the nucleosome core particle, the fundamental building block of chromatin, have demonstrated diffraction beyond 3.5-Å resolution.

Table 5.9. Budget projections by fiscal year for the Structural Biology Initiative ($ in millions—BA)

	1992	1993	1994	1995	1996[a]	1997
Operating expense	0.3	2.7	2.7	2.8	3.4	3.4
Capital equipment	0.8	0.8	1.0	0.8	0.8	0.8

[a]Increment required for detailed design of biological instrumentation for the Advanced Neutron Source.

Continuing Initiative—ORNL Genome Program

The Laboratory is strongly committed to an integrated effort to analyze the mouse genome and, through that, the human genome. New methods that will increase the rate and accuracy for sequencing, 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 DNA 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: one is sequencing by hybridization; others involve various mass spectrophotometric methods of analyzing directly the DNA fragments that are usually subjected to electrophoresis.
- By employing new detection techniques, sensitive and rapid DNA analysis can occur including single molecule detection of luminescence species; mass spectrophotometric 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.

The analysis of mammalian genomes will proceed on several fronts. The analysis of the mouse genome and the interaction with studies on the human genome will proceed as follows:

- develop complete molecular maps and refined functional maps of several specific regions of the mouse genome as models for the human genome program,
- perform fine structure point mutagenesis and physical mapping of the mouse,
- create molecularly tagged mutations throughout the murine genome by insertional mutagenesis using both pronuclear injection and embryonic stem cell techniques,
- use efficient mutagens to generate chromosomal rearrangements for expansion of genomic regions accessible to fine structure molecular structure analyses,
- use mutagenesis techniques to create models of important human genetic disorders that can be analyzed molecularly,
- establish a national data base for transgenic mouse mutants that can be accessible by all researchers, and
- employ artificial intelligence and neural network techniques to identify important DNA sequence patterns.

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 other laboratories are also beginning to submit sequence data to be searched for important human disease genes (Fig. 5.7).

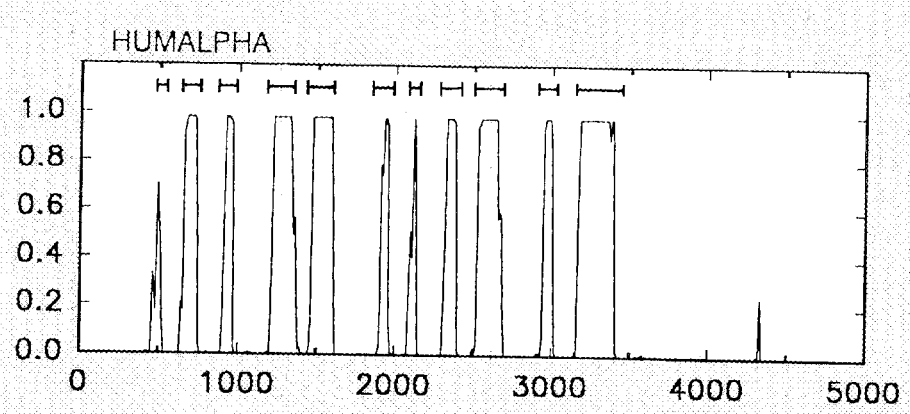


Fig. 5.7. Example of computer recognition of protein-coding potential in a human deoxyribose nucleic acid (DNA) sequence. The gene for human alkaline phosphatase has 11 protein-coding exona; their positions along the DNA sequence (abscissa) are represented by bars at the top of the figure. Plotted below the bars are the outputs from an artificial-intelligence neural network program that has been trained to recognize coding regions in "unknown" DNA sequences. The training involves learning to recognize the frequency of specific trinucleotides and hexanucleotides, the fractal dimensions of the patterns of adjacent nucleotides, and other sequence properties that differ between coding and noncoding regions. In training, the computer "learns" how the parameters differ and from this information is able to localize with greater than 92% accuracy the coding regions in a DNA sequence that it has not seen previously.

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

- a 250,000-mouse colony organized for genetic studies;
- a transgenic mouse facility;
- an NIH-supported data base 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 5.10 lists the budget projections.

Table 5.10. Budget projections by fiscal year for Genome Mapping and Sequencing ($ in millions—BA)

	1992	1993	1994	1995	1996	1997
Operating expense	3.9	4.1	4.5	5.0	5.5	6.1

KP05—Carbon Dioxide Research In the area of global environmental concerns, ORNL has become a center of expertise in the investigation of ecological transport and effects of chemicals in the environment and in the assessment of hazardous wastes, the global carbon cycle related to CO_2-induced climate change, and acid-deposition issues. These activities are the foundation for the ORNL Center for Global Environmental Studies. Housed in the Environmental Sciences Division, the center involves staff members from several other ORNL divisions as well as outside collaborators.

Resource Analysis As part of the Resource Analysis Initiative, ORNL's Carbon Dioxide Information Analysis and Research Program (CDIARP) 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 CDIARP 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 the Carbon Dioxide Information Analysis Center (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. One area of emphasis will be on computer systems development for compiling, analyzing, and handling data for DOE's U.S. Atmospheric Radiation Measurement (ARM) Program. The center's activities will include research in all aspects of the CO_2 issue and technical management responsibilities in the national CO_2 program.

Computer Hardware, Advanced Mathematics, and Model Physics (CHAMMP) The objective of the CHAMMP Initiative 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 dynamic biogeochemical and ecological processes to address the challenging problem of understanding the climate system, to improve the mathematical methods currently needed in general circulation models, and to address the challenging physics of understanding the climate system. In the near term CHAMMP will achieve improved general circulation model performance by taking advantage of existing parallel computers such as ORNL's iPSC/860. ORNL scientists are working in collaboration with staff members from ANL and the National Center for Atmospheric Research to develop a working parallel atmospheric circulation model with terrestrial dynamics.

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. CDIAC staff are assisting DOE in the development of computer and data analysis systems capable of handling the massive amounts of data anticipated over the 10-year lifetime of the program.

Continuing Initiative—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.

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 (e.g., 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, another key technology 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-dropable packages for reading atmospheric or ocean conditions; and instruments for studying cloud formation and 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 the National Aeronautics and Space Administration's (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 primary—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 Work for Others (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 a model that integrates 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, socioeconomic activity, etc. 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.
- Analysis of Options for Implementing Greenhouse-Gas Policy. Governments can choose from a variety of approaches to reducing greenhouse gases: regulation; fiscal incentives; information programs; research, development, and demonstration; and others. We have identified more than 160 applications of those approaches for the U.S. private sector. Currently, we are examining implementation issues—those that may affect negotiations of implementation protocols at any global climate convention dealing with greenhouse gases.
- 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.
- Computer Hardware, Advanced Mathematics, and Model Physics Initiative (CHAMMP). Atmospheric-circulation models pose some of the most complex, computer-intensive problems in scientific research today. ORNL computer scientists and mathematicians are harnessing one of the world's fastest parallel computers for this challenge—ORNL's 128-processor Intel iSPC/860. Later we plan to add a terrestrial-systems model to the adapted atmospheric model 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

Projected Research

- Improved Radiation-Measurement Instruments for the ARM Program. Drawing on ORNL's proven expertise, we propose to develop advanced new instrumentation that will provide better data on global radiation and heat fluxes—data that will allow development of more accurate atmospheric models.
- Infrared Spectrographic Instrumentation. In a collaborative effort with researchers in Canada and the Soviet Union, we will develop an infrared laser-based instrument that can scan the air above a forest and measure trace-gas concentrations and other important phenomena that can help illuminate the interactions of forest and atmosphere.

- 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 overnight 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 also 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.
- A Comprehensive Global Analysis of Water Resources. Despite the current attention to CO_2 and climate change, long-term limits on water resources may prove to be the world's "Achilles heel." Using the large-scale assessment techniques and tools developed for assessment of acid rain effects as a base, we are currently developing a major new initiative in water resources devoted to the predictive understanding of 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 5.11 lists budget projections.

Table 5.11. Budget projections[a] by fiscal year for the Center for Global Environmental Studies ($ in millions—BA)

	1992	1993	1994	1995	1996	1997
Operating expense	9	10	11	11	11	12
Capital equipment	0.1	0.1	0.1	0.1	0.1	0.1

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

KP06—Medical Applications

Nuclear Medicine Research conducted in the Nuclear Medicine Program focuses on the design and development of new tissue-specific radiopharmaceuticals for diagnosis and therapy. New radiolabeled agents are distributed internationally to approximately 20 medical cooperative programs at clinics, universities, and other research institutions for further collaborative preclinical testing and clinical evaluation (Figs. 5.8 and 5.9).

The isotope ^{191m}Ir (half-life 4.9 s) from our ^{191}Os-^{191m}Ir generator has important applications for the diagnosis of heart disease and allows rapid, repeat studies with low radiation exposure. Clinical trials are in progress through our medical cooperative programs in Belgium and West Germany, and over 600 patient studies have been performed. This generator has been licensed recently to Scintillation Technologies, Inc., for commercial applications. Our ^{123}I-labeled ("BMIPP") methyl-branched fatty acid is also in clinical trials. This agent is an important tool in cardiology research and is used for the evaluation of differences in regional myocardial blood flow (perfusion) and fatty acid energy substrate uptake by single-photon computerized tomography.

New radiolabeled maleimide agents for labeling antibodies and other proteins for diagnostic and therapeutic applications are being further developed. The (p-iodophenyl) maleimide (IPM) has been licensed to E. I. du Pont de Nemours & Company for research applications. Monoclonal antitumor antibody labeling studies with radioiodinated IPM conducted in conjunction with medical cooperative investigators have demonstrated good labeling yield and very low loss of radioiodide in tumor-bearing animals. New maleimide analogues have also been prepared for easier introduction of radioactive iodine to this agent.

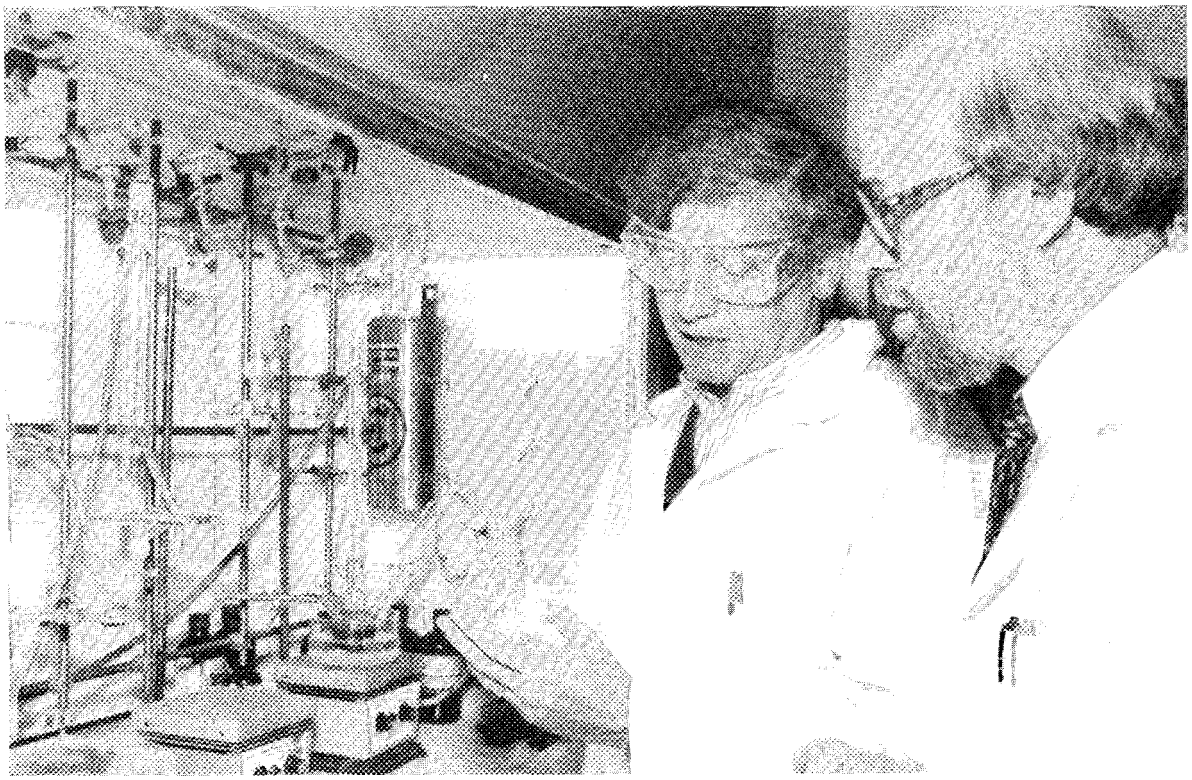


Fig. 5.8. Synthesis of radiopharmaceutical precursors.

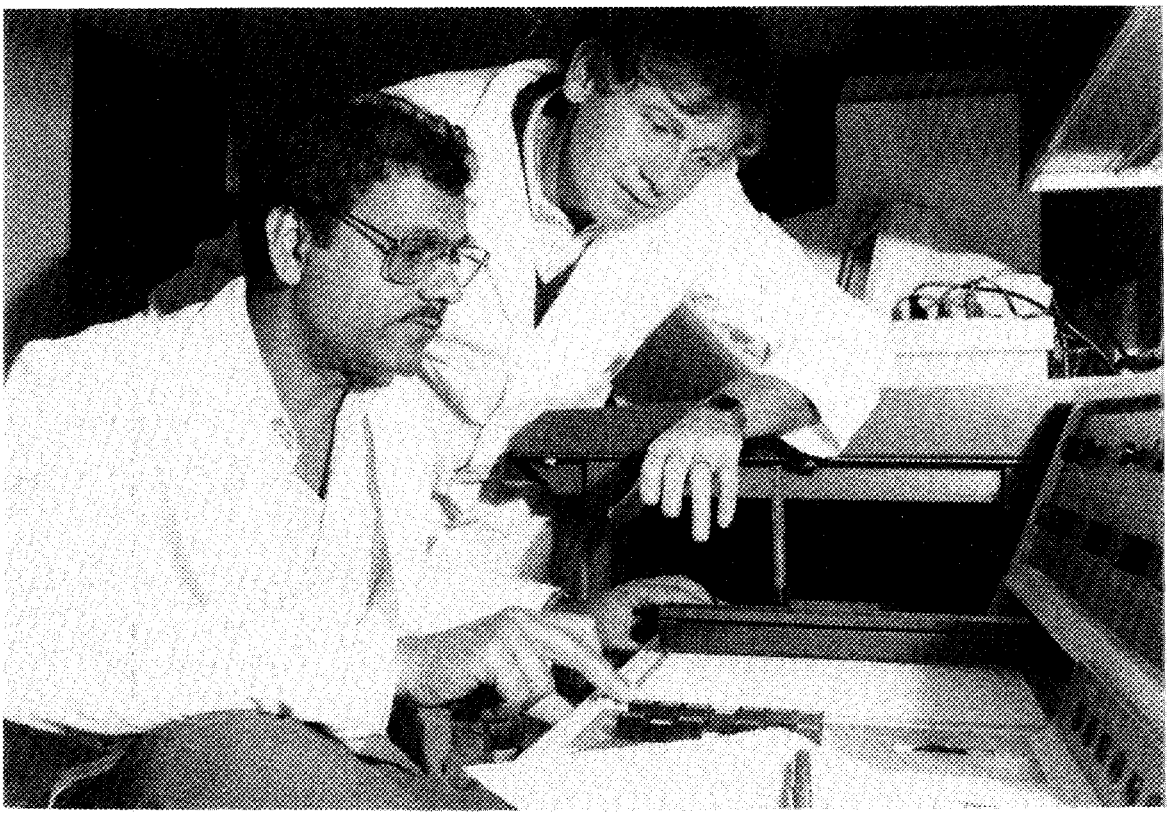
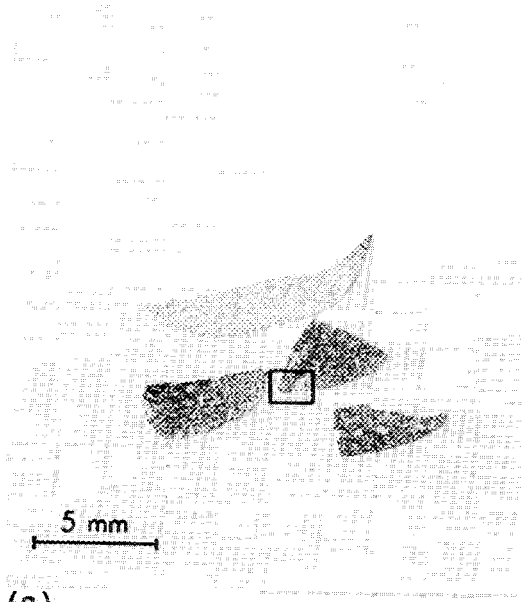


Fig. 5.9. Nuclear magnetic resonance study of radiopharmaceutical precursors.

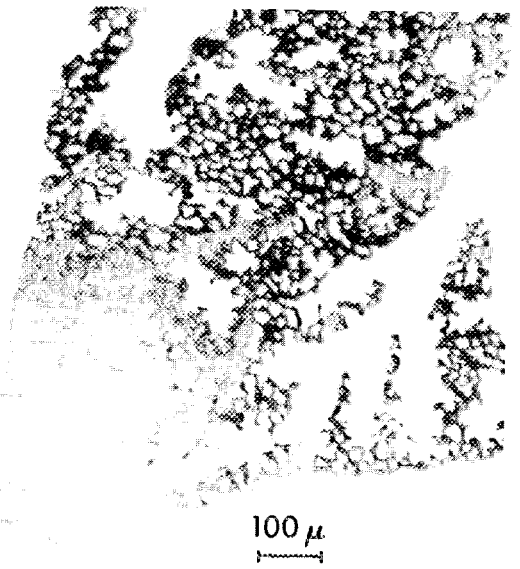
New methods are also being developed for synthesizing bifunctional chelates for attaching radioisotopes of copper (^{64}Cu and ^{67}Cu) and rhenium (^{186}Re and ^{188}Re) to antibodies for therapy and diagnosis. Our studies with ^{64}Cu-chelate antibody complexes are directed at developing an agent for tumor detection with positron emission tomography.

The development and use of radionuclide generators continue to be important focuses of the program. Studies with the ^{188}W-^{188}Re radionuclide generator system developed in our program are continuing to assess approaches for attachment of ^{188}Re to antibodies and particles for a variety of therapeutic applications. Interest in the use of ^{188}Re, an isotope that decays with the emission of high-energy electrons, is widespread among commercial manufacturers and cancer researchers. An additional new generator system under development is the ^{194}Os-^{194}Ir system. Extension of this work is expected to represent the first study of potential applications of ^{194}Ir for therapy.

Radiation Effects 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 (P112), 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 (Fig. 5.10). 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 and their in normal and cancer cells.



(a)



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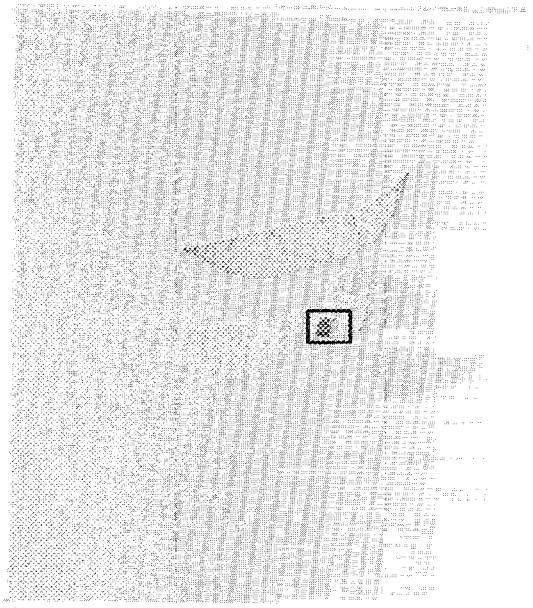

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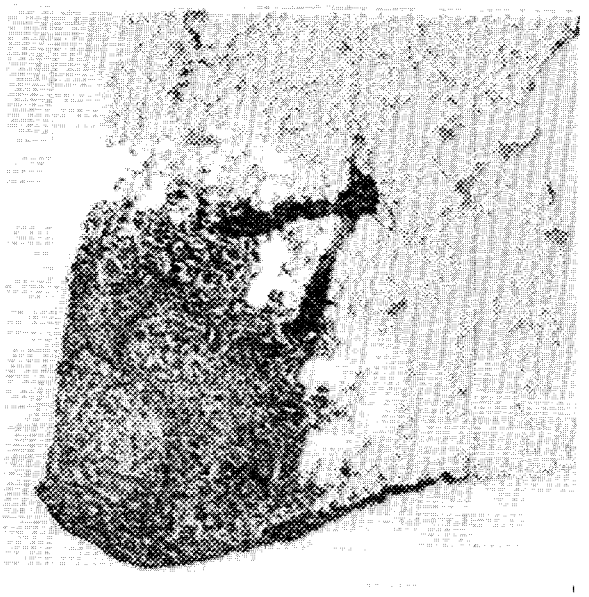

(d)

KS—Superconducting Super Collider

Research in support of the SSC is being performed on nuclear collision models and detector preamplifers, both of which relate to calorimeter detection systems design. Work in support of the SSC is expected to increase rapidly (see the "Summary of Major Initiatives" section).

KT—University and Science Education (Formerly KE)

Through the ORNL-obligated portion of the KT Program, financial support was provided in FY 1991 to over 250 student and faculty research participants under a variety of programs including the science semester programs, nuclear-engineering training experiments, and health physics internships. The KT Program also sponsors visits to ORNL by minority educational institution (MEI) faculty and promotes other activities that encourage university involvement in ORNL missions. Two areas of special emphasis in the KT Program at ORNL are providing opportunities for participants from MEIs and expanding precollege programs. In FY 1991 the KT Program supported the summer appointment of over 30 faculty and students from MEIs. The program also helped support the operation of the Environmental and Physical Sciences Study Center (EPSSC), a program for students in kindergarten through twelfth grade that offers field study modules in environmental science at the Oak Ridge NERP and modules in the physical sciences. In FY 1991 nearly 20,000 students and teachers participated in the EPSSC Program, and demands continue to outstrip available resources. A new program to support high school science education teachers through summer research opportunities has also been developed. The program, the Science Teacher Residency Program, was designed to improve the quality of science and mathematics teaching.

Several other initiatives are under way in the area of precollege programs such as collaboration with local school systems, one of which is support for the Clinch River Environmental Studies Organization (CRESO). CRESO is an organization involving students and teachers from surrounding areas dedicated to student-based, long-term research activities. Seeing CRESO's mission as an extension to the EPSSC, the ORNL Office of Science Education and External Relations provides financial and technical resources for that organization. ORNL also started a Saturday Academy for Computing and Mathematics in which selected high school seniors from 12 area schools and their teachers meet at ORNL facilities for hands-on learning experiences. ORNL is also the lead laboratory in an effort involving five other DOE laboratories in a national precollege Science Teacher Enhancement Program sponsored by the NSF.

ORNL will continue to focus on MEI interactions. An increasing role is expected for Hispanic institutions as the result of two agreements: a Memorandum of Understanding signed with the University of Puerto Rico and a Memorandum of Understanding involving three DOE laboratories and three MEIs including two of Hispanic origin. The Science and Technology Alliance will foster involvement of these educational institutions in long-standing broad program activities that encourage the participation of university students and faculty in ORNL research. KT funds also provide money for cooperative research and development agreements (CRADAs) (see the "Contributions to Economic Competitiveness" section).

New Initiative—Direct Funding for Environment, Safety, and Health (ES&H) Compliance Efforts

To ensure a clean and safe work environment having minimal adverse impact on neighboring communities, ORNL's first priority is compliance with all health and safety laws, regulations, and orders. During the past few years the number of safety and health regulations, together with more detailed and

formal enforcement, has greatly increased. These changes are necessary; however, the resources required to comply fully and effectively with these regulations have not been provided.

In numerous areas past efforts have not been sufficient to comply with today's requirements. Many facilities do not meet current DOE orders based on Occupational Safety and Health Administration (OSHA) regulations. Safety documentation and configuration management also require significant upgrades. The recent Tiger Team Assessment identified many areas where improvements are needed. In developing ORNL's Action Plan, a significant number of the needed actions require funds unidentified at present.

For some time the Laboratory has attempted to handle the funding issues through piecemeal programmatic requests, increased overhead charges, and deferral of other necessary activities. However, these methods cannot effectively upgrade ORNL's compliance efforts in the time frame expected by DOE, Congress, and the public. Resource requirements and priorities have been growing faster than the budget cycle can respond. Overhead contingency funds are used up quickly, and rates cannot be raised any further without severely crippling direct programs. Maintenance cannot be continually deferred without making some facilities uninhabitable. In response to this problem, last year the Laboratory submitted two field-work proposals—one to cover the costs for addressing OSHA requirements and the other to cover other ES&H compliance issues. This year these were separated into eleven field-work proposals for better identification of the specific programs that each would fund. These are

- ORNL Safety and Health—OSHA Safety Documentation. This task provides support for the development of safety documentation (i.e., safety analysis reports and operational safety requirements) of ORNL facilities that do not have an identifiable program sponsor (i.e., those administered by overhead-funded divisions or offices) and a generic safety analysis document describing overall site characteristics at ORNL.
- ORNL Safety and Health—OSHA Regulatory Compliance. This activity is proposed to upgrade ORNL facilities and programs over a 5- to 10-year period to achieve compliance with OSHA standards; the primary areas requiring this enhanced support are (1) full assessment of OSHA noncompliances for evaluating and selecting compliance alternatives and for defining and establishing priorities for abatement plans and funding requirements and (2) corrective actions for noncompliances with emphasis on high hazard items and other noncompliances that create significant vulnerability.
- ORNL Safety and Health—Emergency Preparedness. This activity will allow one-time upgrades to come into compliance for both Tiger Team concerns and those of the 1989 Radiation Protection Program Appraisal of ORNL. Actions include assessing major accident consequences, providing facility hazards information to emergency responders, identifying and correcting potentially serious emergency preparedness deficiencies, classifying emergency events consistent with DOE orders and state plans, acquiring equipment for Radiological Assistance Program response, and upgrading and automating the emergency operations center.
- ORNL Safety and Health—Configuration Management. DOE Order 5481.1B stipulates that safety analysis reports include a detailed comparison of the current plant configuration with current DOE design criteria that highlights and explains any deviations. This activity will develop and implement a configuration management program for the facilities without programmatic sponsors (i.e., administered by overhead divisions).
- ORNL Safety and Health—Natural Phenomena Analysis. As a part of the upgrading of safety documentation for all ORNL facilities, an analysis of the risks caused by exposure to natural phenomena is necessary. This task will provide a generic, sitewide document for use in developing

subsequent safety analysis documentation.

- ORNL Safety and Health—Radiation Protection. This proposal includes activities for measuring, recording, and reporting occupational radiation doses to workers; surveying workplaces; bioassaying; whole body counting; implementating an internal dosimetry quality control program; and instituting a contamination control program and a conceptual design report that describes a line-item project for adequate laboratory and office space to house monitoring activities for occupational radiation exposure at ORNL.
- ORNL Environmental—National Environmental Policy Act (NEPA) Regulations. This task will provide ORNL staff support for preparation of a site environmental report (ER) including development of baseline environmental data and analysis. The ER is a necessary predecessor for development of a reservation-wide environmental impact statement (EIS) by outside parties. The task is dependent on a decision by DOE that a reservation-wide EIS is needed.
- Environmental Upgrade. This task will fund upgrades to site-wide operations and compliance activities to achieve compliance. This includes major reviews and modifications of drains, sewer systems, and other waste streams as required; these systems were in compliance with applicable regulations at the time of construction but do not meet present-day requirements. It also includes staff to support the DOE–state of Tennessee Oversight Agreement as required.
- ORNL Safety and Health—Industrial Hygiene. The proposed funding will be used to develop designated Industrial Hygiene Program areas to levels sufficient for subsequent maintenance by the overhead budget. The program areas include records management, data management, ventilation system evaluation, emergency response capability, facilities upgrade, health protection, program documentation, asbestos management, project review and construction oversight, hazardous materials management, monitoring equipment, measurement assurance and surveillance, compliance programs, baseline monitoring, and support of the oversight agreement with the state of Tennessee.
- ES&H Compliance Training. Recent assessments conclude that a more consistent and interactive training program is needed to provide personnel with knowledge to ensure safe and efficient job performance. This program will address major deficiencies in training for guests/users, Emergency Preparedness, NEPA Regulations, Radiation Protection, Industrial Hygiene, Safety and Environmental regulations, quality assurance, ES&H roles and responsibilities, and craft skills for maintenance personnel. The management of training policies, procedures, and records is also needed for efficiency and consistency.
- ORNL Subtitle I Underground Storage Tank (UST) Compliance. The Subtitle I UST Management Program provides necessary planning, oversight, and technical review to ensure ORNL compliance with Resource Conservation and Recovery Act (RCRA) Subtitle I requirements for underground petroleum and hazardous substances tanks. The program costs reflect the minimum requirements to implement UST tightness testing, inventory management, monitoring, upgrade/replacement or closure (removal), and site remediation.

These proposals provide for the necessary actions at ORNL to upgrade operations in order to move toward compliance with DOE regulations and federal/state laws. It does not provide for continuing, ongoing programs but instead is limited to those actions that must be taken to achieve (not maintain) compliance. Nor do these fund activities that may properly be attributed to a single DOE program office. They have been submitted both to the Office of Energy Research under Program AT and as information items under Program EW to the Office of Environmental Restoration and Waste Management. Table 5.12 lists the amounts requested for FY 1992 through FY 1993. The approval of these proposals would

greatly improve the effectiveness and speed with which ORNL would come into compliance with ES&H laws, regulations, and orders while at the same time maintain its capabilities for important research in the national interest.

Table 5.12. ORNL Safety and Health Field-Work Proposals[a]
($ in thousands—BA)

	Fiscal year			
	1992		1993	
	$	FTE[b]	$	FTE
ERAT850—Safety Documentation	304	1.8	333	2.5
ERAT851—OSHA[c] Regulatory Compliance	16,986	30.6	23,116	30.6
ERAT870—Emergency Preparedness	347	1.0	709	3.1
ERAT871—Configuration Management	674	4.3	441	3.4
ERAT872—Natural Phenomena Analysis	575	3.2	1,210	5.8
ERAT873—Radiation Protection	8,873	11.1	3,976	6.2
ERAT874—NEPA[d] Regulations	6,867	35.2	8,889	31.7
ERAT875—Environmental Upgrade	2,141	7.2	5,982	21.9
ERAT876—Industrial Hygiene	6,006	12.7	4,896	15.0
ERAT877—Compliance Training	3,918	25.8	4,099	24.9
ERAT878—UST[e] Compliance[f]	1,706	6.2	2,000	6.2
Total	48,397	139.1	55,642	151.3

[a]Also submitted to program EMEW. Some values currently being revised.
[b]Full-time equivalent.
[c]Occupational Safety and Health Administration.
[d]National Environmental Policy Act.
[e]Underground storage tank.
[f]New field-work proposal submitted subsequent to FY 1992 budget-submission document.

Assistant Secretary for Nuclear Energy

The Assistant Secretary for Nuclear Energy is the major sponsor of applied nuclear research at ORNL (Table 5.13). Programs funded through this office are multidisciplinary and include nuclear energy R&D, remedial actions, uranium enrichment, and isotope production.

AF—Nuclear Energy R&D

Consolidated Fuel Reprocessing Program
The Consolidated Fuel Reprocessing Program focuses primarily on a broad 5-year collaboration with the Power Reactor and Nuclear Fuel Development Corporation (PNC) in Japan. 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. 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 project. Approximately $9 million more is expected over the next 3 years for hardware.

Table 5.13. Assistant Secretary for Nuclear Energy major program summary
($ in millions—BA)[a]

Budget and reporting code	Major program	Fiscal year 1990	1991	1992	1993
AF	Nuclear Energy R&D	32.8	31.0	38.4	34.5
AJ	Naval Reactors	0	0.1	0.1	0.1
CD	Uranium Enrichment 0.7 0.6	0.4	0.4		
KK	Policy and Management— 0	2.2	1.2	1.5	
ST	Nuclear Energy Isotopes	14.8	3.2	13.7	16.2
Subtotal		**48.3**	**37.0**	**53.8**	**52.7**
CD	Uranium Enrichment 7.8 3.0 (from Energy Systems Central Organizations)	0.0	0.0		
Total		**56.1**	**40.1**	**53.8**	**52.7**
Percentage of total Laboratory funding—BA		11.1	7.9	7.6	6.2

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

The program of collaboration with PNC in liquid-metal-reactor (LMR) reprocessing has focused its R&D activities to support PNC efforts for design, construction, and operation of the Recycle Equipment Test Facility (RETF) in Japan. In a follow-on phase (i.e., Phase II) to begin in FY 1993, ORNL will continue R&D efforts on which agreements have been reached in support of the RETF. Phase III (1997–2003) will encompass the hot operation of the RETF and will begin a 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 Consolidated Fuel Reprocessing Program 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 Consolidated Fuel Reprocessing Program.

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 comparison study of the fuel-cycle facility concepts with the United Kingdom, (2) a rad-hardening of signal-transmission systems with France, and (3) 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 will continue with design

and data reviews through FY 1992 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 in 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 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's support to DOE for this new actinide recycle initiative includes development and assessment of program plans and recommendations concerning chemical, engineering, and licensing issues. DOE anticipates that this program will grow substantially in the near future and expects ORNL's 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 are cosponsored by organizations in Japan.

Primary emphasis in the national High-Temperature Gas-Cooled Reactor (HTGR) Program is on development of a modular HTGR (MHTGR) using steel pressure vessels for the reactor core and steam generators in a side-by-side arrangement. ORNL has lead responsibility for the HTGR Base Technology Development Program. Cost-reduction studies by vendor and utility organizations currently in progress may produce some changes to the technology needs to support design. ORNL's role in the program remains 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 Nuclear Regulatory Commission (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.

Space Nuclear Power Systems In the area of space nuclear power, ORNL continued 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 and Cassini missions. In preparation of this important production activity, ORNL performed an plutonium. The purpose is to remove those

operational readiness review to ensure that all activities associated with the production tasks are in compliance with appropriate health, safety, environmental, and quality requirements. NASA deep space exploration mission plans through FY 2005 portend a continuing need for isotope power systems requiring the continued development and production of improved isotope heat source materials.

ORNL will 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 (i.e., SP-100 Project). 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 FY 2001. However, the multimegawatt space power program, for which ORNL has been conducting materials research since 1984, has been canceled.

CD—Uranium Enrichment

Applying technology derived from DOE programs in Uranium Enrichment (UE) is an increasing and important contribution by ORNL to solving problems of national importance. The Applied Technology Division (ATD) was given the charter by DOE-UE to use uranium-enrichment-derived technology to support DOE, other federal and state agencies, and the private sector. This technology provides significant ORNL strengths in the following areas of science and technology:

- advanced polymeric composite materials;
- advanced manufacturing, prototyping, and characterization of engineered materials;
- structural design and analyses, fluid flow, and mechanics;
- laser and fiber-optic systems;
- remote measurements data and imaging systems;
- power electronics;
- lightweight, high-power motors;
- uranium and toxic-material handling and decontamination; and
- centrifuge separations.

The ATD capabilities include significant expertise that is both unique and synergistic with other ORNL resources. In such areas as organic matrix composite materials and lightweight, high-energy-density motors and generators, ATD provides both national and international technology leadership. Currently, ATD has over 40 sponsors from DOE, the DOD, and the private sector; most of the ATD's funding is provided by DOE.

Current specific DOE applications include composite materials R&D for defense programs and energy research. The ATD also transfers technology to the DOD and to state and private-sector sponsors. The transfer is in the form of licensable intellectual property, reports, prototypes, and workshops. Two composite materials workshops attracted over 500 people in 1990.

The ATD also has the DOE-UE mission of closing out the Gas Centrifuge Program. Termination of the Gas Centrifuge Program started in FY 1985. It includes environmental restoration of 400,000 ft^2 of former centrifuge facilities located on the K-25 Site (at the Applied Technology Facility) through facility decontamination and cleanup, hazardous materials storage and disposal, centrifuge workers health studies, Gas Centrifuge Enrichment Plant claims settlement, and disposition of materials and equipment. The facilities decontamination and cleanup started in FY 1988. At the end of FY 1990, approximately 35% of the former centrifuge facilities had been put to new use for the benefit of DOE. Divisions now occupying and utilizing the space include ORNL's Energy and Chemical Technology divisions and several K-25 Site, Y-12 Site, or Energy Systems divisions (i.e., Environmental Restoration, Y-12 Development Division, Computing and Telecommunications Division, Technical Division, International Technology Division, and Fabrication and Maintenance Division). The remainder of the space

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

One of several unique features of the HTGR is the very high temperature working fluid that affords this concept opportunities for more efficient electrical production and more process heat applications than with other reactor options. Coolant outlet temperatures for other reactors in commercial service (i.e., LWRs and LMRs) are much lower and limited by the metallic components in the core and the fuel. 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 selection can raise the temperature 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 temperature are in the ranges of 300 and 500°C respectively.

The MHTGR offers safety and investment protection features not available in any other fission reactor concept. The HTGR fuel is a helium-cooled, graphite-moderated reactor that contains millions of tiny particles encapsulated in a series of high-temperature coatings and fabricated into fuel assemblies. The MHTGR core has a very low power density compared with LWR and LMR designs (i.e., 6 W/cm^3 compared with 80 W/cm^3 for LWRs and 300 W/cm^3 for LMRs). The low-power-density, high-heat-capacity MHTGR core can easily dissipate decay heat without requiring active safety systems or operator action, but this makes the core larger and thus more expensive. This combination of coolant, moderator, and encapsulation of fuel gives this reactor concept inherent safety features. Despite economies associated with modular construction and elimination of redundant, active safety systems, the overall cost for the MHTGR is estimated to be more expensive than coal plants and about the same as other advanced reactor concepts.

The increased safety available with gas-cooled reactors is attractive to utilities, regulators, and the public. However, both the nuclear industry and the regulatory community agree that currently operating LWRs are sufficiently safe. Neither utilities nor the public are willing to pay more for increased safety margins when the existing product (i.e., 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 a market will exist.

Because of the high-temperature helium cooling fluid, the MHTGR can be designed to operate in the direct cycle (DC), gas turbine (GT) mode. In this mode hot helium coolant gas from the core is used to drive a turbine directly instead of being sent to the heat exchanger to produce steam to drive a turbine (Fig. 5.11). This approach has the potential to simplify the energy conversion significantly—reducing the capital cost and at the same time increasing the energy efficiency by as much as 35%. The capital cost reduction, coupled with the higher thermal efficiency, should make the MHTGR-DC more cost competitive than LWRs or fossil plants.

At this time DOE's MHTGR Program is focused on the steam cycle (SC) rather than the MGR-GT technology development (Table 5.14). However, DOE does have an interest in reducing capital costs for the SC design and has an active program in place. ORNL's initiative includes preconceptual design analyses to provide cost estimates for both the MGR-GT plant and the additional technology necessary (beyond what is being done for the SC) to support the MGR-GT design. The cost comparison and technical feasibility of the MGR-GT is expected to generate substantial interest for the MGR-GT in the industry including nuclear island suppliers, utilities, architect-engineer firms, and component manufacturers. If the initiative is successful, a major technology program focusing on the DC application could result.

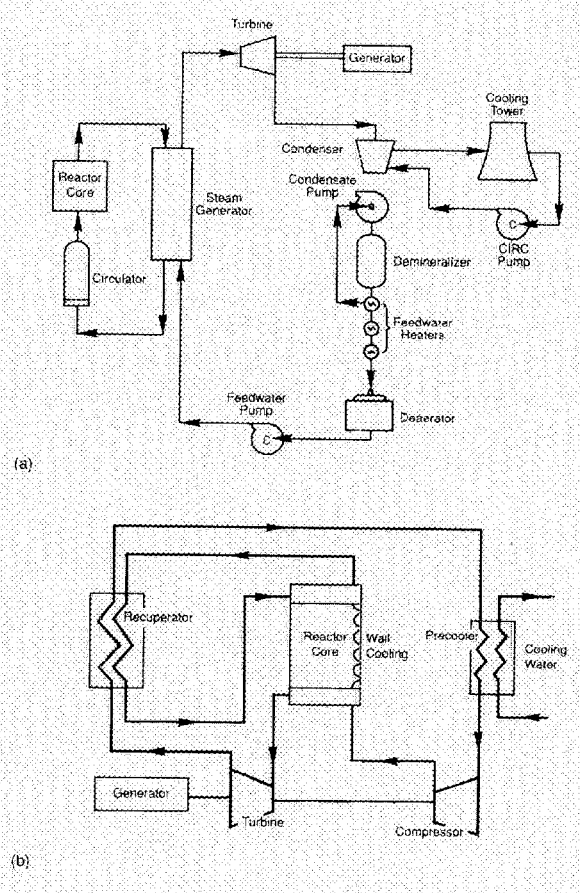

Fig. 5.11. Comparison of flow diagrams for (*a*) steam cycle and (*b*) gas turbine high-temperature gas-cooled reactor electric plants

Table 5.14. Budget projections by fiscal year for the Modular High-Temperature Gas-Cooled Reactor (direct cycle) Initiative ($ in millions—BA)

	1992	1993	1994	1995	1996	1997
Total funding	0.5	1.0	3.0	5.0	7.0	7.0

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

Continuing Initiative—Actinide Recycle

DOE began a reexamination of actinide recycle in FY 1991 to examine the potential for assisting the geologic repository program and fostering the long-term future of nuclear power. Prior work over the past 15 years at ORNL in breeder fuel cycles, and in the earlier major assessment of actinide recycle, places ORNL in a strong position to become a major participant in this program. Preliminary work in support of DOE's planning activity was done in FY 1990.

"Actinide recycle" is a term applied to an advanced nuclear fuel cycle in which a high percentage of the actinides are recovered from spent nuclear fuel and used as fuel in fast reactors where they are ultimately fissioned. This concept extends the conventional concept for coupling LWR and LMR fuel cycles by including recovery and recycle of essentially all of the minor actinides (i.e., americium, curium, and neptunium) in addition to plutonium. The purpose is to remove those long-lived actinides and, thus, reduce the long-term hazards in a geologic repository. Actinide recycle has the potential to reduce the repository hazards issues from a million-year to a thousand-year time frame. This may increase public acceptance of the high-level waste repository while providing some potential to reduce costs by facilitating licensing and decreasing the need for site characterization. Implementation of such a plan would represent a very major change from current policies of spent fuel disposal, and the best expertise in the country is needed to address the many relevant technical and institutional issues.

ORNL is seeking a major role in this program because of its broad base of expertise. This background includes development of aqueous reprocessing for LWR and LMR spent fuels, substantial and diverse involvement with the repository programs, broad capabilities in fuel-cycle systems analysis and economics, and the related important issues of safeguards and nonproliferation. ORNL envisions a major role including technical development and some form of program integration or technical support role to DOE in planning and managing the national program. Support will also be provided in related waste-management and regulatory interactions including overall nuclear fuel-cycle systems studies (Table 5.15).

Table 5.15. Budget projections by fiscal year for Actinide Recycle Initiative ($ in millions—BA)

	1992	1993	1994	1995	1996	1997
Total funding	1.5	2.0	3.0	3.0	3.0	3.0

Continuing Initiative—Oak Ridge Participation in Planning for the National Space Program

Oak Ridge is supporting DOE in its efforts to develop technology of mutual benefit to DOE missions and space-exploration objectives. The national space program objectives have been organized as a multi-agency undertaking with a goal of utilizing and exploiting the best expertise and facilities in the United States for the space program.

To identify an overlap of needs in the space program and basic strengths within the DOE complex, seven science and technology areas have been evaluated:

- nuclear energy technologies, concepts, and applications (e.g., power and propulsion);
- nonnuclear energy technologies, concepts, and applications (e.g., sources, transmission, storage, and energy management);
- environmental assessment and monitoring (e.g., sensing , modeling, and electronics);
- health/life sciences (e.g., radiation effects and shielding);
- manufacturing and construction techniques (e.g., materials, shielding, and robotics);
- high-performance computing; and
- science, mathematics, and engineering education.

Because of the Oak Ridge area's ongoing involvement in DOE's space nuclear power program, we expect to make a significant contribution in the area of space nuclear power and propulsion. Figure 5.12 shows an example of the potassium vapor Rankine cycle power system. We also expect to lead and

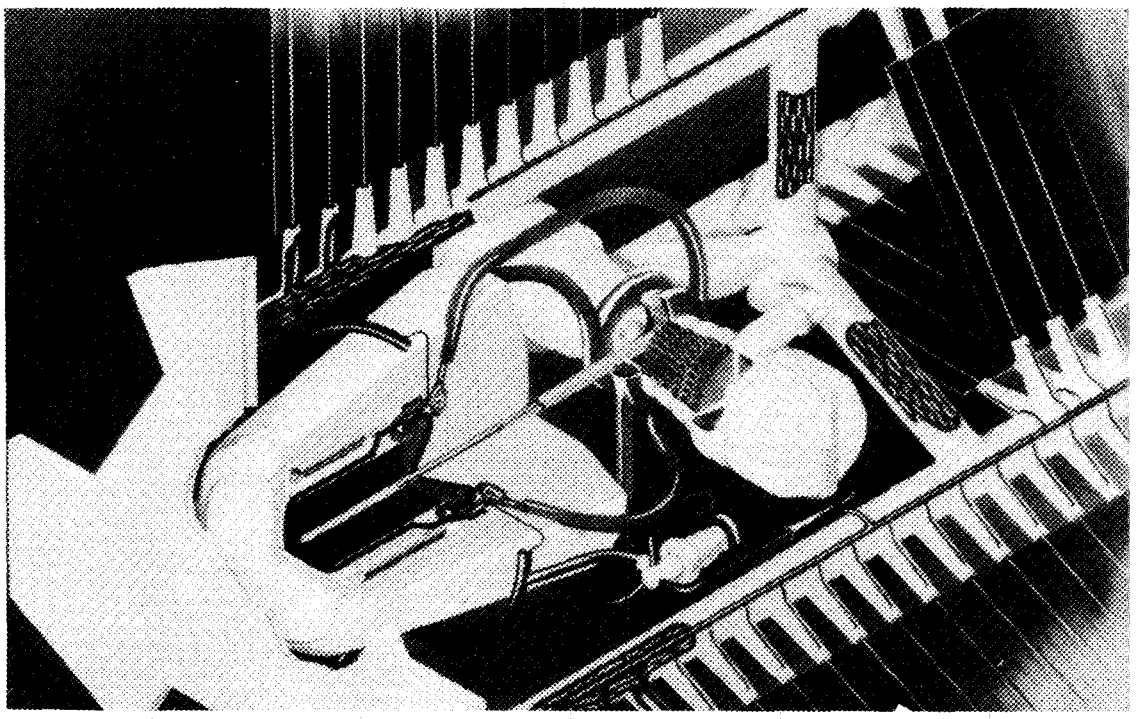

Fig. 5.12. Rankine cycle power system (5 MW) showing cutaway view of reactor and turbine.

make significant contributions to manufacturing and construction techniques (i.e., in materials, shielding, and robotics).

Oak Ridge has key contributions to make in all areas noted and has participated in the national planning. Oak Ridge will lead the program in manufacturing and construction, an area of heavy

emphasis in debris shielding, robotics, and materials research. Figure 5.13 shows an example of the shielding technology. This is a critical role involving the integration of bench-top science with materials development as well as prototypic testing of systems that must be space compatible—industrial partners will be included as part of the team. Efforts to strengthen the collaboration between ORNL and NASA facilities continue. This is envisioned to be a growth area in work for others. The budget needed to support this effort (tentative at this time) is expected to evolve over several years (see Table 5.16).

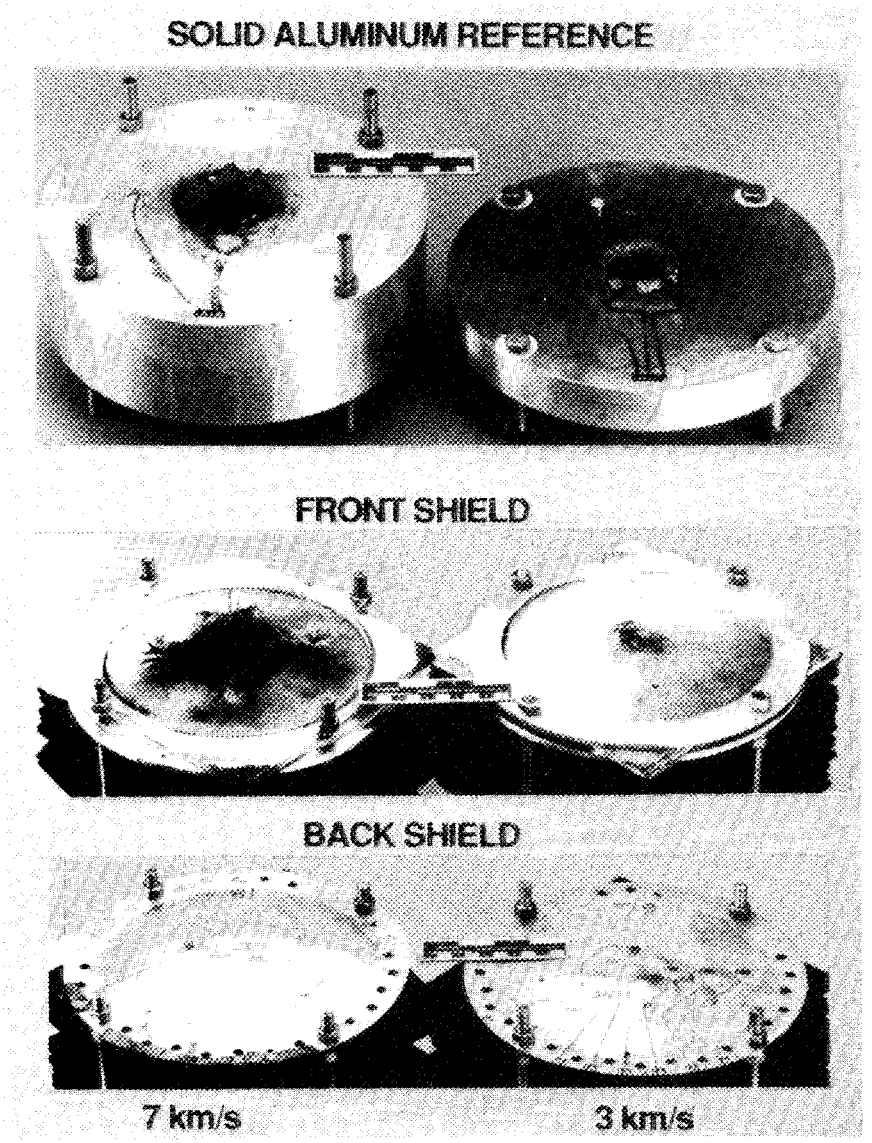

Fig. 5.13. Comparison of impact damage for two velocities (3 and 7 km/s) on solid and "bumper" shields tested at ORNL.

Table 5.16. Budget projections by fiscal year for the DOE and Oak Ridge Space Program
($ in millions—BA)

	1992	1993	1994	1995	1996	1997
DOE budget request	30	70	100	150	200	200
Oak Ridge						
DOE	2	5	10	12	15	20
Work for Others	2	5	10	12	15	20

(about 270,000 ft^2) is under surveillance and maintenance.

The FY 1991 ER budget request of $3.2 million to continue the facilities environmental restoration (decontamination and cleanout) was not funded. The FY 1992 request for $3.4 million also was not funded. The FY 1993 request of $4.93 million is under review.

The combination of a uranium enrichment mission to complete the activities associated with the termination of the centrifuge program and the charter to make the enrichment-based technologies available for DOE, other state and federal agencies, and the private sector affords a unique opportunity for ORNL to enhance its reputation as a national materials technology resource and its reputation for technology applications. Significant initiatives within this mission include

- the implementation of an organic matrix composites initiative with UT;
- the application of system-engineering modeling and risk-analysis techniques to support critical facility operating and safety systems;
- the application of advanced power and electronic control and machinery technology to support motor and generator development;
- the development of a motor concept that capitalizes on superconducting materials technology to provide a lightweight, high-power motor or generator (a collaborative effort of ATD, Energy, and Fusion Energy divisions);
- the application of unique electro-optic measurements and data-recovery systems for noncontact (or remote) and nonintrusive measurements in hazardous environments over temperatures ranging from cryogenic temperatures to 1400°C; and
- the use of facilities formally used by the Gas Centrifuge Program for the Environmental Restoration Program and the use of restored facilities for expanded programs by the ATD and other ORNL divisions.

Non-ATD-based CD work at ORNL is composed of a collection of on-call assignments related to cost studies, economic analysis, information management, and standards development. In each case the CD support makes up a modest fraction of the total support at ORNL for this work.

ST—Isotopes

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 utilizes 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.

The actions of DOE in establishing the Isotopes Production and Distribution Program and providing funding only through a revolving fund that must be replenished through sales and services has had a negative impact on research projects that require the use of enriched stable isotopes. Further, the loss of programmatic support has left the enriched isotope supply program without a dependable source of funds; this places the future continuation of the supply program in jeopardy and dependent on large industrial companies predominantly owned by foreign organizations.

Prior to FY 1990, DOE and its predecessors had provided programmatic funding to ORNL for the supply of enriched stable isotopes produced in the electromagnetic calutrons at the Y-12 Site to the research community. During that period DOE-ER support represented from 35 to 50% of that necessary to operate the Calutron Facility plus more than $1 million in capital equipment funds. Most of the ER funds (i.e., ~$1.7 to 2.0 million/year plus capital equipment) were provided through the Office of Basic Energy Sciences—Chemical Sciences and were designated (1) for surveillance and maintenance of the Actinide Calutron Facility; (2) for maintenance and administration of the Research Materials Collection (RMC), an inventory of enriched stable isotopes available for loan to research projects involving nondestructive use; and (3) for general operation of the calutrons. In addition, prior to FY 1988, the Office of Basic Energy Sciences—Physical Sciences provided ~ $0.3 million/year for preparation of special physical forms (e.g., targets, foils, thin films, etc.) of the enriched isotope products in the Isotope Research Materials Laboratory, and prior to FY 1987, the Office of Health and Environmental Research provided ~ $0.4 million/year for supply of enriched isotopes to research projects in medical, nutritional, and geological sciences.

In effect, the ~ $2 million funding previously supplied by DOE represented a subsidy to researchers either in the form of (1) free loans from the RMC for nondestructive uses or (2) below-cost sales for destructive uses. Most of the isotopes used by researchers have little or no demand in the sales market and accordingly do not represent a resource for revenues needed to sustain the sales program. Thus when the ER funds were transferred to the revolving fund in FY 1990, the supply program lost its largest and most dependable "customer," and the enriched isotope products prepared for that customer were of insufficient value in the marketplace to bring in revenues equivalent to the previous subsidy. Attempts to raise revenues by charging "leases" for the materials that were previously provided to researchers free of charge through the RMC have been unsuccessful because the majority of researchers cannot afford the leases. Indeed, some of the researchers also cannot afford to return RMC materials that have been incorporated into unique research equipment.

Dependable, programmatic funding for the supply of enriched stable isotopes is needed to enable future research to be continued in the many fields where the use of these materials is essential. These include nuclear physics and chemistry, biology, nutrition, medicine, geology, environmental sciences, etc. Because the sponsors of research in these fields are diverse, recruiting of a single sponsor who could act as a "broker" for the others is believed to be the most workable arrangement.

Office of New Production Reactors

The ORNL New Production Reactors (NPR) Program (Table 5.17) is focused into four primary areas:

- materials and structures development in support of the NPR Heavy-Water Reactor (HWR);
- materials development in graphite, in-reactor metals and ceramics, vessel materials, and heat transport system (primarily steam generator) materials for the NPR MHTGR;

Table 5.17. Office of New Production Reactors major program summary
($ in millions—BA)[a]

Budget and reporting code	Major program	Fiscal year			
		1990	1991	1992	1993
NP	New Production Reactors	16.9	9.7	0.4	1.1
Transfers from other DOE laboratories		0	6.1	4.5	2.0
Total[b]		**16.9**	**15.8**	**4.9**	**3.1**
Percentage of total Laboratory funding—BA		3.3	3.1	0.7	0.3

[a]Figures include operating BA, capital equipment, and construction, if any.
[b]Figures assume selection of the modular high-temperature gas-cooled reactor technology.

- 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 NPR options including the LWR.

Because of budget constraints, DOE's Office of New Production Reactors will down-select among NPR options to only one plant technology at a Record of Decision on December 29, 1991. The Record of Decision will be based on the results of an EIS being prepared for each technology at each candidate DOE site (i.e., Savannah River, Idaho, and Hanford), the cost evaluation of each technology and site combination, and key enabling or inhibiting technical issues associated with each technology. ORNL's FY 1991–FY 1992 major 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—potentially simplifying the design of HWR Emergency Core Cooling Systems and making the safety case for placing core-damage events into beyond design-basis;
- implementation of a graphite oxidation kinetics test to support eliminating "graphite fire" as a credible MHTGR accident;
- 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 and (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;
- development of a data base for stress corrosion-resistant low-carbon Alloy 800 for the MHTGR steam generator eliminating the need for an austenitic to ferritic bimetallic weld; and
- testing of MHTGR fuel irradiation to demonstrate the predictable low in-pile failure rate of coated fuel particles and core conduction cooldown testing of irradiated coated fuel particles to demonstrate that significant fission product release does not occur below 1600°C.

The Record of Decision will affect the projected NPR work at ORNL. Because of ORNL's significant involvement (i.e., $13 million in FY 1991) in the MHTGR portion of the program,

selection of either the HWR or LWR will either significantly limit or virtually eliminate ORNL participation in the program.

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.

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), transportation and system integration (DB04), and program management and technical support (DB05). Overall, work in Program DB is uncertain at this time. DOE awarded a management and operating (M&O) contract in early CY 1991 for the OCRWM work, and the funding in future years could change significantly downward depending on what portions of the effort are transitioned to the M&O and when this transitioning occurs. Table 5.18 shows the OCRWM budget summary without the impact of the M&O contractor; similarly, the following also does not consider the impact of the M&O contractor because definitive guidance on this impact has not been received.

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. Current work primarily consists of performing technical reviews and evaluations of various Yucca Mountain Project reports. No work in this area is anticipated beyond FY 1992.

The transportation and system-integration component of the program supports two activities at ORNL. The first, the Transportation Operations Project Office (TOPO), provides technical support and undertakes specific technical work supporting the DOE–Chicago Operations Office's lead responsibility for OCRWM's Transportation Project Office. TOPO's current work areas include technical support to the transportation institutional studies, transportation economic and systems analyses, operations/support system development, and transportation program management. Significant activities include developing a plan for guiding DOE's support of states and tribes in

Table 5.18. Office of Civilian Radioactive Waste Management major program summary ($ in millions—BA)[a]

Budget and reporting code	Major program	Fiscal year			
		1990	1991	1992	1993
DB	Nuclear Waste Fund	7.1	8.7	11.4	14.1
Percentage of total Laboratory funding—BA		1.4	1.7	1.6	1.7

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

training for emergency response; assessing the trends in the rail industry as they may impact the shipment of spent nuclear fuel beyond 1997; developing assessments of the transportation capabilities at reactor sites; developing and maintaining shipment routing information and computer codes for calculating routes; performing systems tradeoff studies; developing site-specific service planning documents; assessing the impacts of, and defining alternatives for, applying the Standard Disposal Contract signed between DOE and utilities; defining a specification for a tractor to carry the legal-weight truck cask system; providing operational inputs to cask designs; assessing options for heavy-haul and intermodal transport; and performing preconceptual cask maintenance facility design studies.

The second activity, the system-integration component, is embodied in the Waste Systems Data and Development (WSDD) Project. WSDD has responsibilities in developing analysis capabilities, implementing systems engineering studies, supporting the Radiation-Shielding Information Center (RSIC), performing reactor interface assessments, developing waste acceptance criteria, and maintaining the Waste Characteristics Data Base. WSDD activities are concentrated on data, calculational techniques, and modeling common to the major components of the DOE-OCRWM waste management system; these activities assist OCRWM in performing design and trade-off studies required for the establishment and operation of an integrated, efficient, high-level nuclear waste-management system.

Support in the DB04 area could be reduced significantly in the coming years depending on decisions made by DOE concerning the work to be accomplished by OCRWM's M&O contractor. The program-management and technical-support component of OCRWM supports a major portion of the Integrated Data Base Project, which contains DOE's official spent fuel and radioactive waste inventories and projections through 2020, and the review and evaluation of the environmental aspects of key OCRWM documents. Support in this area is expected to remain stable.

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 5.19).

Table 5.19. Assistant Secretary for Defense Programs major program summary ($ in millions—BA)[a]

Budget and reporting code	Major program	Fiscal year			
		1990	1991	1992	1993
GB	Weapons Activities	1.9	0.2	0.4	0.5
GD	Nuclear Safeguards and Security	0.7	0.6	0.7	0.7
GE	Materials Production	5.5	7.0	11.9	13.0
Total		**8.1**	**7.8**	**13.0**	**14.2**
Percentage of total Laboratory funding—BA		1.6	1.5	1.8	1.7

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

New Initiative—Advanced Materials Design Methods and Manufacturing

The U.S. government has designated high-performance materials, materials processing, and advanced manufacturing as critical technologies that merit special consideration and urgent attention in government spending. These technologies are key to returning the United States to a strong position of global competitiveness. The strong technology position that the United States has in materials should be converted into products produced in the United States using our best manufacturing and processing technologies.

ORNL can make a significant contribution to this critical need and proposes to start a new initiative entitled Advanced Composites Design Methods and Manufacturing to concurrently address design and manufacturing processing issues 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, in-and-on process control, and fabrication expertise will serve as the springboard for this thrust.

A triad of activities usually must be included to develop and to use advanced materials successfully: (1) material science, (2) design methods and structural integrity validation, and (3) manufacturing and processing science and engineering (Fig. 5.14). ORNL has a demonstrated track record in materials science having introduced some of the most advanced ceramic composites, intermetallic alloys, carbon composites, and graphites. It is now time to complete the triad by starting a new initiative to include (1) design methods and structural integrity and (2) manufacturing science and process engineering.

As the first part of this initiative (to be led by the Engineering Technology Division) we envision establishment of a Design Methods and Structural Integrity Center for Advanced Materials. The center's primary mission would be to establish appropriate design and fracture assessment methodologies for emerging advanced materials—accelerating their application and transfer to U.S. industry. Efforts will involve several disciplines and divisions (e.g., Metals and Ceramics, Applied Technology, and

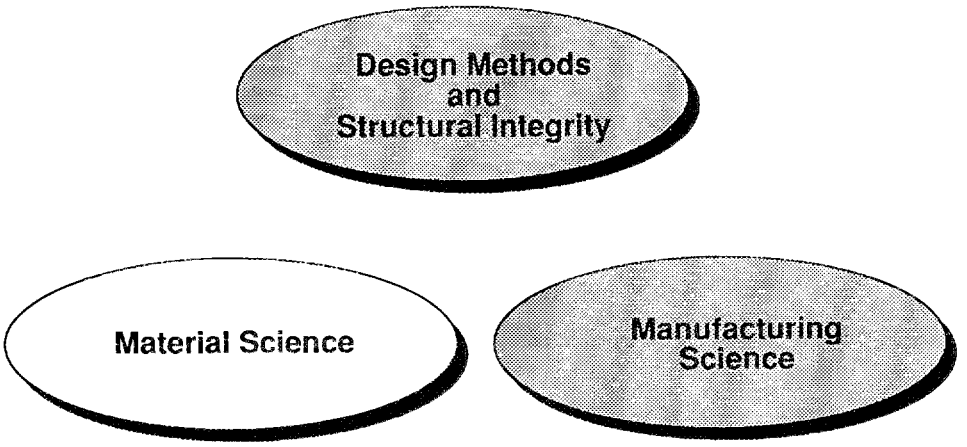

Fig. 5.14. ORNL'S three-part approach to the successful development and use of advanced materials.

Engineering Technology). While the center would primarily address high-temperature composite materials (e.g., ceramic, carbon, and intermetallic matrix composites), design methods development and application for other composite materials (polymeric composites) would also be spun off as appropriate.

The second part of the initiative will be the development of a Manufacturing and Processing Technology Integration Center (MAPTIC) that will focus on the science and processing technology for manufacturing precision high-temperature composites. Materials of interest would again include ceramic-ceramic, carbon-carbon, and ceramic-intermetallic composites. The programs of the centers will develop, validate, and integrate emerging technologies, 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, endurability and performance. Emphasis will be placed on producibility by using 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 because design of, and with, composite materials must be done concurrently with manufacturing and process development. By the integration of the activities of MAPTIC with other capabilities across the Laboratory, it is envisioned that the U.S. industrial base will be more rapidly invested with DOE technologies.

Each of the activities of this initiative will emphasize networking across ORNL divisions as well as across other Energy Systems organizations. Strategic relationships will be formed with industries, universities, and other government agencies. Target applications include optics, baffles, shields, and space platforms; aerospace vehicles and engines; high-temperature process equipment; and heat engines. 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. Table 5.20 lists budget projections.

Table 5.20. Budget projections by fiscal year for Advanced Materials Design Methods and Manufacturing Initiative ($ in millions—BA)

	1992	1993	1994	1995	1996	1997
DOE funding	0.5	1.5	2.8	5.8	17.3	8.6
Non-DOE funding	0.4	1.0	1.8	3.3	5.0	8.0
Total	**0.9**	**2.5**	**4.6**	**9.1**	**22.3**	**16.6**
Operating expense	0.7	2.5	4.2	8.1	11.3	14.6
Capital equipment	0.2	0.3	0.4	1.0	1.0	2.0
Line-item construction	0	0	0	0	10.0	0

GB—Weapons Activities

Tasks and projects supported by Program GB include some support to the RSIC, the development and maintenance of a cost–risk analysis methodology for nuclear weapons production, the development and maintenance of state-of-the-art analytical methods used to analyze transportation packages, and technical program assistance for the New Production Reactor Program.

GD—Safeguards and Security

Begun in 1985, this activity involves two projects: (1) the detection of high explosives in real time by the technique of mass spectrometry/mass spectrometry (MS/MS) and (2) the implementation of independent fissile inventory-verification and tank-calibration techniques by mass spectrometry. Both efforts are to remain relatively constant, although the first task could accelerate if a major breakthrough is achieved.

The MS/MS technique has been demonstrated to be a powerful analytical method to analyze complex mixtures for targeted compounds. It thus has potentially direct applicability to the detection of vapors from high explosives. A very sensitive, small, high-explosive vapor detector is under development. A laboratory prototype was designed and constructed and is undergoing field testing.

GE—Materials Production

This program includes the Mark 42 Processing Program, the ^{252}Cf Industrial Sales/Loan Program, the ^{233}U Storage and Distribution Program, and the NFS Plutonium Scrap Storage Program. The Mark 42 Processing Program involves the recovery and purification of transuranium element isotopes (i.e, ^{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 Los Alamos National Laboratory (LANL) and Lawrence Livermore National Laboratory (LLNL). One Mark 42 target will be processed each year in the REDC at ORNL, and the program is expected to continue for approximately 10 years. Preparations for processing were made in 1989 and 1990 and processing will begin 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 Radiochemical Engineering Development Center, Building 7930. Facilities for purification of ^{233}U, located in the Radiochemical Processing Plant at ORNL, were placed in standby in 1989. Shielded, safeguarded storage and some distribution of ^{233}U are being continued. A new program was initiated in 1991 to provide safeguarded storage of plutonium scrap that had been generated at the Nuclear Fuel Services Plutonium Facility in Erwin, Tennessee.

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 (AS/CE) (Table 5.21). Ultimate goals are to increase energy efficiency and the use of renewable resources; this would help increase our industrial competitiveness, reduce our dependence on oil imports, reduce the cost of energy to consumers, and reduce the environmental impact of energy production activities.

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. Operation of two Conservation Program user facilities, the High Temperature Materials Laboratory (HTML) and the Roof Research Center, has been a key element in interactions with industry.

A continuing initiative, Energy Technologies for Developing and Eastern European Countries (below), seeks funding from DOE-CE programs. In this initiative ORNL is continuing to seek expanded support for research believed to be especially important to future industrial competitiveness.

Noteworthy changes in expected funding levels during the planning period are the following. Increased funding for Program AK reflects increased requirements for high-temperature superconductivity. Increased interest in environmental advantages of biomass may result in higher funding for Program EB. Increased funding is predicted for Program ED in expectation that the continuous fiber ceramic composites initiative and the waste-reduction program will entail increased

activity. A substantial increase in Program EE will result from new initiatives in advanced materials such as materials for lightweight vehicles, electric vehicles, and alternative-fuel vehicles.

Table 5.21. Assistant Secretary for Conservation and Renewable Energy major program summary ($ in millions—BA)[a]

Budget and reporting code	Major program	Fiscal year			
		1990	1991	1992	1993
AK	Electric Energy Systems	4.4	10.9	12.0	13.6
AL	Energy Storage Systems	0.4	1.2	1.4	1.3
AM	Geothermal Energy	0	0.5	1.4	0.5
CE	Hydropower	0.2	0.2	0.7	1.3
EB	Solar Energy	3.5	4.7	10.7	10.7
EC	Building and Community Systems	9.5	13.0	16.1	20.5
ED	Industrial Energy Conservation	2.0	1.9	3.7	4.2
EE	Transportation	21.4	20.8	26.1	30.6
EF	State and local programs	1.8	2.4	1.9	0.7
EG	Multisector	6.1	5.9	7.0	7.5
Total		**49.3**	**61.5**	**81.0**	**90.9**
Percentage of total Laboratory funding—BA		9.8	12.1	11.5	10.7

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

Continuing Initiative—Energy Technologies for Developing Nations (Including Eastern Europe)

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. 5.15). Energy use by developing 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.

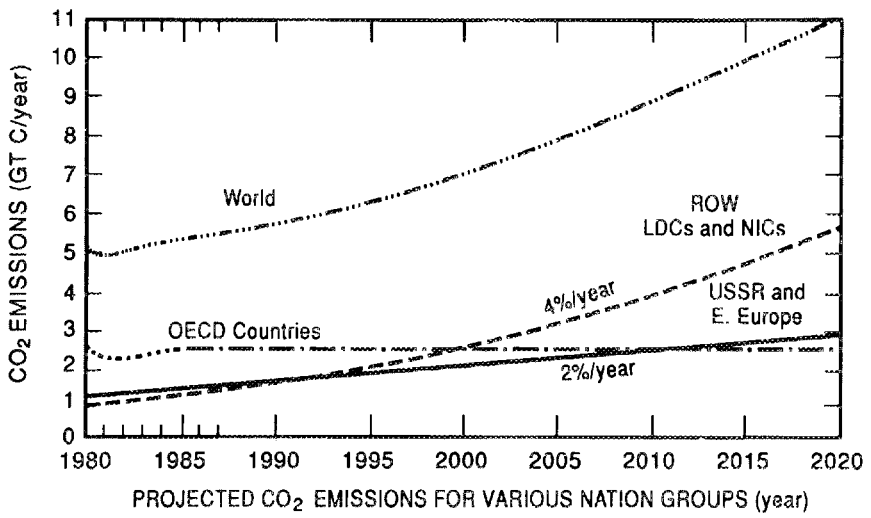

Fig. 5.15. Projected CO_2 emissions for various nation groups shown are simple exponential extrapolations of the actual growth rates observed for 1977–1987. OECD—Organization for Economic Cooperation and Development; Eastern Europe and Soviet Union included Poland, East Germany, Czechoslovakia, Hungary, Romania, Yugoslavia, and Bulgaria; ROW—rest of the world including China. The ROW includes all of the developing nations (LDCs) as well as newly industrialized nations (NICs). Subtracting out the NICs delays the time when CO_2 emissions of LDCs cross those of the OECD countries by about 7 years.

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:

- 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., U.S.S.R., 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 U.S.S.R. 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 (SEED), 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:

- Related support from AID's Office of Energy and from various missions and regional offices should continue.
- 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 to $200 million per year. Table 5.22 indicates the budget proposed for the ORNL initiative in this subject area. About $1 million of the total in each year, FY 1992–FY 1996, has been included in the projections for Program EF in the "Resource Projections" section.

Table 5.22. Combined DOE and Work-for-Others operations budget projections by fiscal year for Energy Technologies for Developing Nations Initiative[a]
($ in millions—BA)

	1992	1993	1994	1995	1996	1997
Non-DOE (AID)	0.5	0.8	1.0	1.0	1.0	1.0
DOE	0.5	1.2	3.0	7.0	8.0	9.0
Total	**1.0**	**2.0**	**4.0**	**8.0**	**9.0**	**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.

AK—Electric Energy Systems

Scientific breakthroughs in high-temperature superconductors have provided a challenge to the scientific community to develop enabling technologies for electrical conductors used in many commercial applications. At the same time, the need to find more effective mechanisms for government and industry to work together was recognized. These two needs have led to the creation of High-Temperature Superconductivity Pilot Centers at ORNL, LANL, and Argonne National Laboratory. The ORNL pilot center has established cooperative research projects with industrial firms to develop high-temperature superconductivity to a commercial technology. To expedite and to encourage the formulation of cooperative projects, DOE has established a novel set of business arrangements. The agreements regarding ownership of intellectual property are flexible, additional safeguards have been put in place for the protection of proprietary data, and a simplified model cooperative agreement is being used. These arrangements have stimulated intense industrial interest. Several cooperative projects with leaders in superconducting technology have been started, and formulation of additional projects is limited only by availability of DOE funds.

By the end of March 1991, 18 cooperative agreements had been signed providing for ORNL researchers to work with a wide variety of large companies, small businesses, and universities that are in the vanguard of superconductivity development. Under a cooperative agreement with American Superconductor Corporation, a bismuth oxide wire was fabricated that achieved the noteworthy combination of current density and magnetic field at relatively low temperatures. In another agreement with Westinghouse and the University of New Mexico an aerosol pyrolysis process was developed for synthesizing phase-pure submicron Y-123 powders. The powders proved to

have higher current densities than samples from commercially available powders.

A second, closely related project is ORNL participation in the Superconducting Technology for Electric Power Systems Program. This program seeks to develop the technology for large-scale applications requiring high current in magnetic fields; immediate focus is on the development of practical high-temperature superconductors. The ORNL project is determining the effects of processing variables on grain-boundary resistance and also investigating the effects of powder preparation technique on conductor critical current density. The Pilot Center and Superconducting Technology for Electric Power Systems programs have recently been combined under the name Superconducting Technology Program for Electric Energy Systems.

In other Electric Energy Systems work during FY 1990, ORNL successfully organized a joint initiative to investigate detection techniques for S_2F_{10} including the EPRI, the Bonneville Power Administration, the Empire State Electrical Energy Research Corporation, and Ontario Hydro. This initiative was organized under a CRADA. In future years the funding for application of high-temperature superconductivity (an ORNL initiative) is expected to increase substantially. Support for other activities in Electric Energy Systems may remain constant.

AL—Energy Storage Systems

ORNL has been assigned responsibility for field management of Thermal Energy Storage Systems in the areas of diurnal storage and industrial processes. The three goals are to identify advanced storage concepts, to establish technical feasibility and economic promise, and to promote implementation in the private sector through technology transfer activities.

An extremely promising concept developed over the past several years consists of a composite mixture of a metallic salt and a higher-melting ceramic. Initial experimental results and economic analyses are encouraging. When sufficient funds are available, this concept will be tested in subscale size for recovery of waste heat from a brick kiln. A number of other concepts are being developed including development of a self-releasing, submerged ice maker; development of a direct contact ice storage system using a unique compressor; use of ammoniated salts for chill storage; and use of latent thermal storage in building materials for storage of solar energy. Congressional appropriation levels for thermal storage have been sharply reduced in recent years. Indications are that the current level may be maintained for the next several years.

AM—Geothermal Energy

ORNL participates in two areas of the geothermal program. The first consists of studies that provide input data for models of the chemical reactions in geothermal systems. Some important consequences of such reactions include reservoir plugging, scaling of heat transfer surfaces, and excessive corrosiveness in brines and steam, all of which can limit the lifetime of the resource and increase the cost of geothermal energy. The second geothermal project, commencing in FY 1991, is the assessment of environmental impacts of the proposed geothermal development on the island of Hawaii.

CE—Hydropower

ORNL has the lead support role to DOE for environmental R&D to solve problems that currently constrain hydroelectric development in the United States. In FY 1991 DOE's Hydropower Program was restored and is expected to grow as part of the department's commitment to renewed emphasis on renewable energy development. ORNL is currently completing the first phase of a critical review of environmental mitigation practices required in hydropower development. This research will expand into development of improved design criteria for mitigation and new assessment methods for problems such as instream flow needs, dissolved oxygen protection, and fish passage at dams. The environmental research supported at ORNL by DOE's Hydropower Program has broad applicability to many water resource management problems.

EB—Solar Energy

ORNL has been assigned field-management responsibility for biomass feedstock development. The goal of this work is to develop cost-competitive terrestrial energy crops for conversion to gaseous and liquid fuels. Interdisciplinary research is conducted in the fields of physiology, genetics, silviculture, and agronomy. Much of this research is subcontracted to research institutions in crop-producing regions to investigate crop production in various climates and soil conditions. The program is closely coordinated with that of the Solar Energy Research Institute, where processes for conversion of biomass into liquid fuels are under development.

The two major areas of research are short-rotation woody crops and herbaceous crops. Production questions at the technical level are being addressed in a complementary manner for both areas. Feedstock linkages with specific conversion technologies are being considered to identify and to develop appropriate energy qualities in the feedstocks. Priority regions and crops have been identified to focus research on the most relevant topics. Private-sector cost sharing is strongly encouraged in subcontracted research efforts.

The issue of global climate change provides an important additional incentive for the consideration of biomass as an energy source. Preliminary analyses have shown that high-intensity tree plantations could sequester a significant portion of U.S. CO_2 emissions. Alternatively, biomass could be used to meet a significant part of U.S. energy requirements without contributing to CO_2 emissions (Table 5.23).

Both herbaceous and woody biomass production continue to approach the economic targets of being competitive with coal as the research yields more complete data on species selection and optimal cultural conditions. For instance, recent economic analysis of hybrid poplar plantations yielding 16 dry Mg/ha/year gave production cost estimates of $17/Mg and total delivered price of chips of about $40/Mg. These prices would be close to the price of coal in some parts of the country.

Research is expected to continue during the planning period with steady progress toward the ultimate goal of economic fuel production. Increasing interest in biomass as a strategy to reduce global climate change may result in higher funding levels in future years. ORNL participation

[illegible]

	Technology status			
	Present		Advanced	
Yield (tons/acre/year)	6		10	
Land base (106 acres)	35		103	
Ethanol generated (109 gallons/year)	17.3	(12%)[a]	111.4	(79%)[a]
Electricity generated (1012 kWh)	0.26	(9%)[b]	2.16	(78%)[b]
Net gasoline carbon displaced (million tons C/year)	34	(3%)[c]	272	(20%)[c]
Net coal carbon displaced (million tons C/year)	67	(5%)[c]	470	(35%)[c]

[a]Percent of current U.S. gasoline consumption.
[b]Percent of current U.S. electric power production.
[c]Percent of total U.S. fossil fuel carbon emissions.

in the Solar Energy Program also includes planning activities in the Integrated Electric Utility Program for lesser-developed countries.

EC—Buildings and Community Systems

ORNL is responsible for field management in four project 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. During FY 1991, construction was completed on an Envelope Systems Research apparatus that will be used to study properties of insulations manufactured with blowing agents that do not contain chlorinated fluorocarbons (CFCs). This joint DOE-industry project is more than 50% industry-funded.

In Existing Buildings Research, ORNL is responsible for single-family and commercial buildings. Recent progress on modeling attic radiant-barrier performance has verified that it is now possible to predict closely the energy savings that can be obtained from such installations. Radiant-barrier insulation is emerging as a cost-effective retrofit measure, particularly when installed with conventional insulation in southern regions of the country. Increasing emphasis in Existing Buildings Research is being given to hot, humid climates. With reduced congressional funding levels, this project is able to address only the most urgent problems.

Building Equipment Research seeks to conserve energy by developing improved heat pumps for heating and cooling buildings. Both electrically driven and heat-actuated heat pumps are included. A major task in electrically driven systems is the search for acceptable substitutes for CFCs as working fluids. The international agreement (the "Montreal Accord") to limit worldwide use of CFCs has increased the urgency of this task. During the past year ORNL generated the first known experimental data on system performance of seven potential CFC substitutes. ORNL worked with E. I. du Pont de Nemours & Company develop the mixture of refrigerants that is now the leading candidate as a near-term replacement for R12. Three types of heat-actuated heat pumps are under development by industrial subcontractors: absorption cycle, Stirling cycle, and internal combustion. ORNL has identified a new absorption cycle (i.e., the triple-effect cycle) that has up to twice the cooling performance potential of the best current cycles; patent rights have been waived to Energy Systems. This technology could give the United States a multibillion-dollar worldwide market in cooling systems for commercial buildings.

The Buildings Technology Transfer project provides resources for strategy development and evaluation of technology transfer. This activity also conducts outreach efforts that go beyond the scope of R&D projects for building components. Specific current tasks include working with universities on education and training; providing support to the Office of Building Technologies in producing publications; and coordinating with other outreach organizations such as the Conservation and Renewable Energy Inquiry and Referral Service, the Office of Scientific and Technical Information, the National Appropriate Technology Assistance Service, the Center for Analysis and Dissemination of Demonstrated Energy Technologies, and the DOE Office of Technical and Financial Assistance.

During the past several years ORNL has taken a lead role in exploring the potential of Integrated Resource Planning (also called Least Cost Planning). In this concept utility planning includes end-use energy conservation options in addition to energy supply options. During FY 1990 DOE selected Integrated Resource Planning as an initiative area, and ORNL funding for this project is expected to increase in FY 1991 and subsequent years.

ED—Industrial

ORNL performs applied R&D tasks for several projects for the Office of Waste Reduction Technologies under the Deputy Assistant Secretary for Industrial Technologies. We are responsible for two continuing projects in Waste Energy Reduction. The first of these, Materials for Waste Heat Utilization, provides materials technology

support to DOE and its contractors in support of advanced heat-exchanger development. Recent work has included evaluating the corrosion of several candidate ceramics for industrial projects and evaluating coatings to reduce corrosion. ORNL has also completed the design and construction of a controlled temperature corrosion probe. This unit has been tested in the ORNL steam plant and has been modified for use in an industrial furnace. In the second project, Chemical Heat Pumps, the objective is to develop heat-pump technology for recovering industrial and process waste heat. A heat- and mass-transfer apparatus is being used to provide data in support of two industrial subcontractors.

A major assessment was completed in FY 1990 to determine the extent of industrial needs for new technologies in continuous fiber ceramic matrix composites. This task produced a detailed R&D plan for the program start in 1991 and will be followed in future years by significant research activities. A new project, development of a magnetohydrodynamic atomization nozzle for spray casting steel, was also initiated in FY 1989 in coordination with EG&G Idaho and the Massachusetts Institute of Technology. This project is part of the program known as the Metals Initiative. Technical feasibility of the ORNL process has been demonstrated at laboratory scale. The next step is to build and to operate equipment to demonstrate the process on a larger scale.

The level of activity by ORNL on Industrial Programs is expected to increase substantially during the planning period in response to growing recognition of the central role of materials technology in industrial energy efficiency. We also expect to have a significant role in the new industrial waste-reduction program.

EE—Transportation

ORNL is responsible for two projects in transportation: Ceramic Technology for Advanced Heat Engines and HTML user program. ORNL also participates in the Alternative Fuels Utilization Program and the Advanced Heat Engines Program. The Ceramic Technology for Advanced Heat Engines Project is developing the industrial technology base for reliable, cost-effective ceramic components in advanced automobile and truck (i.e., diesel and gas turbine) engines. The energy-savings potential of ceramics in transportation 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. Among many achievements during the past year was the completion of a 2-year R&D effort in powder characterization, which was part of an international cooperative program between the United States, West Germany, and Sweden. In addition, an update report for the Ceramic Technology Project Database was issued. Unlike previous reports that concentrated on one class of ceramics per report, this report contained new test results on several classes of ceramic materials including zirconias, silicon carbides, and silicon nitrides. Possible new programs in advanced materials for transportation systems are under discussion including materials for lightweight vehicles, materials for electric and hybrid vehicles, and materials for vehicles using alternative fuels. Detailed assessments of these technologies are planned for FY 1992.

The HTML, which was completed in FY 1987, houses laboratories and special equipment to support the Office of Transportation Systems, other DOE offices, universities, and industry in advanced materials research. Four original user centers are operated within the HTML with funding designated for this purpose. After 4 years of operation, user agreements had been established with 60 universities, 80 industrial firms, and 4 government laboratories. Approximately 200 separate research projects had been completed or were under way. During FY 1990 two new user centers were organized and will be fully staffed by the end of FY 1992. A new initiative to expand the usefulness of the HTML through a fellowship program has been proposed. The initiative would provide postdoctoral, faculty, and industrial fellowships, each for a limited period of research, in one of the

HTML user centers. The rapid increase in applications for use of the HTML is expected to require increased funding in future years.

The objective of the Alternative Fuels Utilization Project is to establish a technical data base on the utilization of nonpetroleum fuels including gaseous fuels, alcohols, and fuels derived from shale or tar sands. The Federal Methanol Fleet Project was completed and was successful in providing important information to vehicle manufacturers as well as policymakers. Subcontracts with Detroit Diesel Corporation and Caterpillar, Inc., to improve heavy-duty methanol engines, continue under ORNL direction. A team of ORNL researchers developed and tested diesel fuels containing high percentages of alcohols. These fuels appear to be functional in standard diesel engines and show modestly reduced nitric oxide emissions. Increased funding on alternative-fuels research may be forthcoming in the next few years as a result of intensified emphasis on regional air quality problems. However, the extent of ORNL funding is uncertain because of a DOE decision to transfer field management responsibility to the Solar Energy Research Institute.

ORNL activities in Advanced Heat Engines have continued to expand gradually. Projects in advanced emission controls and alternative fuel component technologies are being developed. A project in Transportation Systems Research provides analysis of transportation data such as vehicle fuel economy, sales, and technology trends. A new project in automotive air conditioning is exploring the possibilities for eliminating CFCs from automobile air conditioners.

EF—State and Local Programs

During FY 1990 ORNL assisted DOE in developing a plan for evaluating the impact and potential of its Weatherization Assistance Program. ORNL will implement the plan over the next 3 to 4 years using a nationally representative sample of program participants, a sample of fuel oil participants from nine northeastern states, and matched control groups. Data on numerous aspects of the program, its participants, and its unserved eligible clients will be gathered from a variety of sources including local and state agencies, household surveys, on-site building inspections, fuel and indoor-temperature monitoring, electric and gas utilities, and the 1990 Census of Population. An ORNL initiative is Energy Technologies for Developing Countries (including Eastern Europe). Proposed tasks under this initiative are discussed in the "Assistant Secretary for Conservation and Renewable Energy" subsection.

EG—Multisector

ORNL has a continuing role in several research activities formerly known as Energy Conversion and Utilization Technologies. The role of these activities is to span the gap between basic science and engineering development of conservation technologies. Thus they provide the technology base for efficiency improvements in several end-use sectors. ORNL participates in the Advanced Industrial Concepts (AIC) Materials, Tribology, Biocatalysis, Thermal Sciences, and Combustion projects.

In AIC Materials, ORNL is conducting research on a number of projects in both engineered industrial materials and materials manufacturing. DOE recently established ORNL as Technical Manager for the entire AIC Materials Program. In Tribology the ORNL research is in the area of ceramic friction and wear. Our research in Biocatalysis seeks to develop continuous bioreactor technologies for production of chemicals such as ethanol. In Thermal Sciences we are investigating several innovative conversion concepts. The ORNL effort in the Combustion project consists of the development of microemulsions for transportation fuels.

During FY 1990 numerous milestones were reached in AIC Materials. Turbocharger prototypes made of the Ni_3Al alloys developed at ORNL in the program are being fabricated and evaluated by the Cummins Engine Company. Numerous tests are being performed to evaluate their acceptability for use in large diesel engines. In another AIC Materials task significant progress was made in the

development of high-temperature superconducting magnets for a high-efficiency motor. Y-123 films grown on single-crystal yttria-stabilized ZrO_2 substrates were found to have a critical temperature of 85 K. In Tribology a definitive study of the friction and wear behavior of nickel aluminides has been published. ORNL's expectation is that EG funding will remain at the current level or increase in future years.

An additional project within the EG program is the evaluation of the Energy-Related Inventions Program. The evaluations consider both the effectiveness of the program in helping inventors to commercialize their ideas and the extent of resulting energy savings. An ORNL analysis of the cost of commercialization showed that for $1 spent in the initial year of the research, $37 more were needed to reach limited production. Technologies supported by the program have achieved $400 million in sales through 1988. Estimated tax returns generated by these technologies suggest a significant return on the public investment in this program.

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 (SPR), 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 environmental, safety, and health 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 Materials Program—comprise the major portion of the coal budget. The materials area is expected to have a significant

Table 5.24. Assistant Secretary for Fossil Energy major program summary ($ in millions—BA[a])

Budget and reporting code	Major program	Fiscal year			
		1990	1991	1992	1993
AA	Coal	5.6	5.8	6.1	8.2
AC	Petroleum	0	0.1	0.1	0
AZ	Innovative Clean Coal Technology	0.5	0.5	0.8	0.9
CB	Naval Petroleum and Oil Shale Reserves	[b]	0	0	0
SA	Strategic Petroleum Reserve	0.2	0.3	0.5	0.5
Total		**6.3**	**6.7**	**7.5**	**9.6**
Percentage of total Laboratory funding—BA		1.2	1.3	1.1	1.1

[a]Figures include operating BA, capital equipment, and construction, if any.
[b]Less than $0.1 million.

increase in FY 1992. From FY 1992 through FY 1997, additional efforts will focus on solid state electrolyte systems, development of advanced coatings and claddings, inorganic membranes, and technology transfer.

Fiber-reinforced ceramic composites with improved strength and toughness are being produced by the 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 to 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 corrosion 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 the evaluation of chaotic components of fluidized-bed combustion.

With a specially modified scanning electron microscope, erosion processes can be observed in situ, leading to valuable data on the mechanisms of the erosion process and an understanding of the formation and adherence of protective oxide scales. 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.

ORNL has a commitment to transfer the technology developed in the Fossil Energy Materials Program to others in the fossil energy community. ORNL is working with two industrial firms and the Morgantown Energy Technology Center (METC) to produce and to test sintered porous metal filters made from iron aluminides. Another significant technology transfer effort is a subcontract with 3M Company for the development and transfer to industry of a process for fabricating full-size ceramic fiber–ceramic matrix composite filters utilizing technology developed at ORNL. Support will be provided to METC by evaluating environmental concerns related to R&D projects sponsored by the METC.

Coal conversion work at ORNL involves bioprocessing of coal and the evaluation of coal-derived liquids produced from mild gasification processes. Bioreactor concepts that maximize coal solubilization and product yields are being examined. For the first time bacteria have been shown to interact with a bituminous coal in a hydrogen environment for the biological solubilization of coal.

AC—Oil

Technical and analytical support will be provided to DOE for the new Oil Research 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 Program (CCP) includes support in the areas of environment and materials. The CCP is jointly funded by DOE and industrial organizations. Three solicitations have been completed by DOE, and fourth and fifth solicitations for the CPP are planned for future years. An important part of ORNL's involvement

in the CCP is environmental technical support to DOE in the preparation of NEPA reviews of site-specific projects. Materials failure analyses (critical to the success of advanced clean coal technologies) continue to be conducted for the Pittsburgh Energy Technology Center. Work related to the CCP is expected to increase in the next 5 years.

CB—Naval Petroleum and Oil Shale Reserves

ORNL staff members are performing assessments of a naval petroleum reserve in Wyoming and a Naval Oil Shale Reserve in Colorado. The objective of this work is to conduct an Environmental Compliance Assessment covering all environmental regulations to strengthen the environmental programs at these sites and to ensure full environmental compliance.

SA—Strategic Petroleum Reserve

ORNL is performing work for the SPR Program in two areas: (1) development of a baseline data set for specific metals and organic chlorine in crude oils and (2) assistance to the SPR 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 increase moderately 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 regulation; 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).

HA01—Environment, Safety, and Health

The Laboratory continues to provide technical support to all offices under the deputy assistant

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			
		1990	1991	1992	1993
HA	Overview and Assessment	4.6	6.6	5.4	5.0
HR	Epidemiologic Activities	0[b]	0.2	0.2	0.2
HS	Office of Security Evaluations	0	0.1	0.1	0.1
Total		**4.6**	**6.9**	**5.7**	**5.3**
Percentage of total Laboratory funding—BA		0.9	1.4	0.8	0.6

[a]Figures include operating BA and capital equipment, if any.
[b]Previously funded under KP and CD programs.

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. We also anticipate an expanded technical support role with the Office of Environmental Compliance in FY 1992. We assist them in developing compliance policy and in evaluating the compliance status of DOE facilities nationwide.

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, NEPA training, and assistance at DOE Headquarters. Major initiatives that relate to the secretary's ten-point plan and Secretary of Energy Notice SEN-15-90, "Revisions to DOE Order 5440.1C and to DOE Guidelines" (February 5, 1990) include (1) providing technical support for evaluating compliance with NEPA at all DOE facilities (e.g., Tiger Teams) and (2) training mid-level DOE management staff and operating contractors to ensure that personnel responsible for NEPA compliance understand the statute, the Council for Environmental Quality regulations, the DOE NEPA guidelines, and their responsibilities in the preparation of the various levels of NEPA documentation.

Environmental Audit ORNL expertise in environmental and health risk analysis is available to help prioritize actions required to comply with environmental regulations, federal facilities agreements, and consent orders.

Safety Policy and Standards Sponsors of the Emergency Technology Program (ETP) are reorganizing and will modify the mission of the program. Under the ETP, ORNL personnel review and assist in emergency planning and preparedness for environmental protection and public safety.

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.

HR01—Epidemiologic Activities

ORNL provides technical support to epidemiological activities conducted for the assistant secretary for environment, safety, and health. Under HR0105, support regarding environment, safety, and health is provided in the area of conducting epidemiologic research activities including the Radiation Effects Research Foundation. Under HR0135, support is provided to K-25 Site worker safety studies. The HR-funded activities at ORNL were previously funded through Biological and Environmental Research OHER and other DOE offices.

HS01—Office of Security Evaluations

ORNL provides support to various activities associated with the development and maintenance

Continuing Initiative—Center for Risk Management

The Center for Risk Management, established with the support of the Environmental Restoration Program, 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 ($ in millions—BA)

	1992	1993	1994	1995	1996	1997
Operating expense	8.0	10.0	12.0	12.0	12.0	12.0

New Initiative—Health Physics Instrumentation Center of Excellence

Recent attention to environmental, safety, and health 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 to be 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 Health and Safety Research Division (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 radiation calibration facilities of Energy Systems, combined and upgraded, will form the nucleus of the experimental portion of ALERT. Specifically, ALERT will involve 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 and environmental chamber at Portsmouth Gaseous Diffusion Plant, and miscellaneous radiation sources and facilities at Paducah Gaseous Diffusion Plant, the Y-12 Plant, and the X-10 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 the National Institute of Standards and Technology (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 the R&D needs of the health physics community as well as national needs associated with performance test programs and NIST calibration activities (Table 5.27).

Table 5.27. Budget projections by fiscal year for the Health Physics Instrumentation Center of Excellence Initiative ($ in millions—BA)

	1992	1993	1994	1995	1996	1997
Total funding	1.8	2.0	1.6	1.6	1.5	1.5

of state-of-the-art analytical methods used in the review of safety analyses reports for packagings. These methods include computer codes and other advanced assessment tools.

Office of 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, and Technology Development. ORNL receives funding in all of these categories, with the bulk of the funding being supplied through the Energy Systems central organization in FY 1991 and beyond (see Table 5.28).

Environmental Restoration

ORNL has approximately 200 contaminated sites divided into 12 waste area groupings (WAGs) that will require remediation. The ORNL

Table 5.28 Office of Environmental Restoration and Waste Management major program summary ($ in millions—BA)[a]

Budget and reporting code	Major program	Fiscal year			
		1990	1991	1992	1993
EW	Environmental Restoration and Waste Management—Defense	33.9	7.7	11.3	18.7
EX	Environmental Restoration and Waste Management—Nondefense	19.9	5.2	0.2	0.1
	Landlord	0	9.2	66.2[b]	0
Subtotal		**53.8**	**22.1**	**77.7**	**18.8**
	DOE funding from Energy Systems Central Organizations				
EW	Environmental Restoration and Waste Management—Defense	0	29.9	66.1	117.7
EX	Environmental Restoration and Waste Management—Nondefense	0	23.0	18.4	28.7
Subtotal		**0**	**52.9**	**84.5**	**146.4**
Total		**53.8**	**75.0**	**162.2**	**165.2**
Percentage of total Laboratory funding—BA		10.6	14.8	23.0	19.4

[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 (ER) Program consists of the following major activities: preliminary assessments/site inspections to identify, evaluate, and document newly discovered sites; development of a comprehensive watershed, groundwater, surface water, and sediment monitoring program; surveillance and maintenance (S&M) of sites to ensure adequate containment and control prior to closure; remedial investigations/feasibility studies to determine the nature and extent of contamination and to evaluate remedial-action alternatives; interim corrective measures (ICMs) or removal actions to contain, remove, or treat contamination to protect human health and/or the environment prior to completion of final site remediation; final site closure/remediation and validation; and long-term monitoring. Regulatory drivers include the Resource Conservation and Recovery Act (RCRA); the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA); a pending interagency agreement between DOE, the EPA-Region IV, and the Tennessee Department of Environment and Conservation (TDEC); and the Tennessee Oversight Agreement between DOE and TDEC.

Major 1991 accomplishments include implementation of a time-critical removal action to control contaminated sediment transport from the White Oak Creek Embayment (WOCE) to the Clinch River; removal of contaminated debris from the Building 3001 Storage Canal in preparation for interim closure; submittal of remedial investigation (RI) plans for WAGs 2 (White Oak Creek/White Oak Lake), 11 (White Wing Scrap Yard), and 13 (Environmental Research Areas); and the WAG 6 [Solid Waste Storage Area (SWSA) 6] RCRA Facility Investigation report to EPA-Region IV and the TDEC for approval.

Major activities planned for 1992 and 1993 include completion of the WOCE removal action, completion of Building 3001 Storage Canal interim closure, completion of ICMs at WAGs 11 and 13, submittal of the WAG 6 closure feasibility study, regulatory approval of the WAG 6 closure Record of Decision, completion of WAG 6 pre-closure activities in preparation for closure implementation in 1994, and completion of RI field activities in WAG 5 (SWSA 5).

An integral part of the ER Program is the contaminated facilities and decontamination and decommissioning (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 the Environmental, Safety, and Health Management section for additional details.)

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 the conduct of 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 will be reduced sharply in UMTRAP in FY 1991, when nearly all inclusion surveys will be completed.

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 for FY 1991 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.

Waste Management

The mission of Waste Management (WM) is to provide quality waste-management capability in compliance with applicable requirements. This mission is carried out through strategic planning; development of new or upgraded facilities; and routine collection, treatment, storage, and disposal of waste. Radioactive (low-level as well as transuranic), hazardous, mixed radioactive and hazardous, medical/infectious, and solid sanitary/industrial wastes are managed by the WM component. Waste forms include gaseous, liquid, sludge, and solid. WM operates 34 facilities at the Laboratory, and covers ongoing operation and upgrade of ORNL WM facilities needed to support the programmatic missions of DOE. Additionally, it provides for management of wastes produced as a result of 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 the Environmental, Safety, and Health Management section for additional details.)

Technology Development

The Technology Development Program was initiated to provide R&D support for the ER and WM activities on the Oak Ridge Reservation. Research, development, demonstration, testing, and evaluation activities are directed to finding ways to decrease workers' and public exposure to hazardous substances and to providing more efficient and effective solutions to problems on the Oak Ridge Reservation and at other DOE sites. The technologies being developed are shared among the DOE sites and with the private sector for use in solving environmental problems. Funding is anticipated to increase over the planning period.

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.[1]

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

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

Order 5480.1; (3) security systems and procedures are adequate to prevent unauthorized entry; and (4) all hazardous chemicals have been removed.

This program is currently funded through DOE's Office of Environmental Restoration and Waste Management (EM) and is managed by Nuclear Energy (NE). The program budget is $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 range for each year. A major activity planned for FY 1992 is a detailed planning and budgeting exercise for the shutdown activities to be performed in FY 1993 and FY 1994.

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 5.29).

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 in

- 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.

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; and other DOE contractors and operational offices (Table 5.30).

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

Table 5.29. Energy Information Administration major program summary ($ in millions—BA)[a]

Budget and reporting code	Major program	Fiscal year			
		1990	1991	1992	1993
TA	Collection, Production, and Analysis	1.0	1.0	1.3	1.4
Percentage of total Laboratory funding—BA		0.2	0.2	0.2	0.2

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

Table 5.30. Other DOE programs and installations
($ in millions—BA)[a]

	Fiscal year			
	1990	1991	1992	1993
Office of Administration and Human Resource Management	0.9	0.4	0.2	0.2
Office of Policy, Planning, and Analysis	1.2	2.1	3.0	2.5
Federal Energy Regulatory Commission	0	0.6	2.5	2.5
Assistant Secretary for International Affairs and Energy Emergencies	0.1	0	0.2	0.2
DOE contractors and operations offices	32.9	24.6	28.9	31.5

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

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.

Office of Policy, Planning, and Analysis

Work for the Office of Policy, Planning, and Analysis (PE) 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 and analyses in support of the Interagency Task Force on Alternative Fuels. ORNL will also perform research and analyses in support of PE's role in developing the National Energy Strategy.

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, a study characterizing critical loads of sulfur deposition acceptable for maintaining aquatic and terrestrial ecosystem structure and function, and a study projecting future pollution resulting from power plant life extension. A new effort has begun 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.

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, the Oak Ridge Operations Office, 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 an expert-system prototype to process Bonneville's microwave communication system alarms.

Other ORNL Programs

Reactor Operations

This ORNL organization is responsible for the operation, maintenance, and support of ORNL's research reactors so that they safely, reliably, and efficiently fulfill their intended research, isotope-production, and training functions. The Research Reactors Division carries out this work by interacting with 11 other ORNL divisions and organizations that either conduct reactor-based research or support reactor operations.

Laboratory and division management are committed to maintaining a proactive approach in operating the research reactors. This approach will include 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—as well as the requirements of ES&H, Institute of Nuclear Power Operations (INPO) guidance, and compliance with DOE, OSHA, EPA, and DOT regulations—will continue to be emphasized.

ORNL's research reactors include one "Class A" reactor (HFIR), and three "Class B" reactors [i.e., Tower Shielding Reactor II (TSR-II), the Health Physics Research Reactor (HPRR), and the BSR]. The fuel has been removed from the HPRR, and it is to be shut down unless a potential user/sponsor with available resources for restart comes forward. In addition, two reactor facilities [i.e., the Critical Experiments Facility (CEF) and the Pool Critical Assembly] are in standby status, and one reactor [i.e., the Oak Ridge Research Reactor (ORR)] has been shut down and defueled.

May 18, 1991, was the one-year anniversary of HFIR's return to full-power operation. The HFIR is one the world's most powerful research reactors and operates at a maximum power level of 85 MW. Its uses include 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. The HFIR is staffed around the clock, and its operating crew goes through a program of intense training and rigorous examinations to maintain their certifications (Fig. 5.16).

TSR-II was restarted in December 1989 and resumed its primary research program, the Japanese/American Shielding Program of Experimental Research (JASPER), in January 1990.

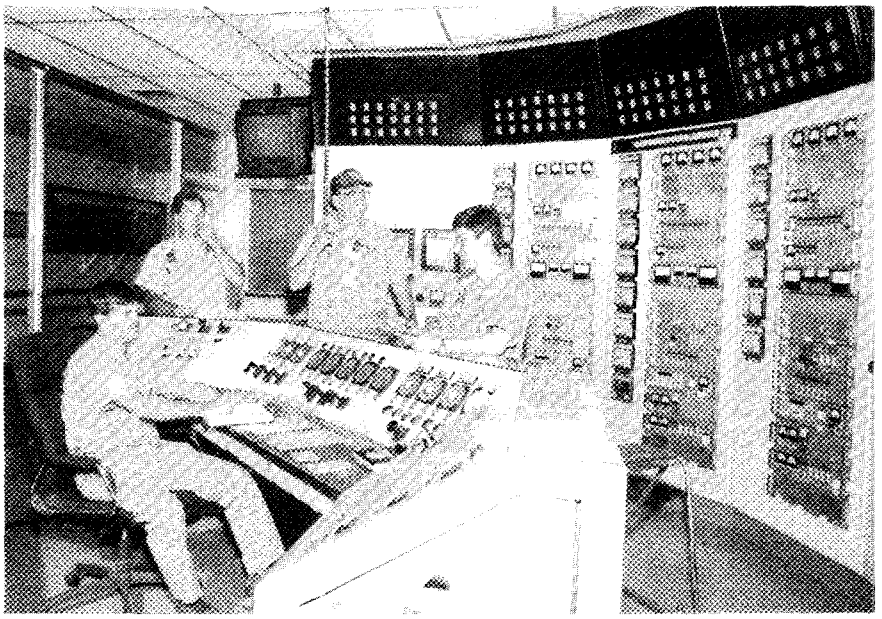

Fig. 5.16. Nuclear reactor controllers J. G. (Jeff) Kirk (seated) and (standing, left to right) W. E. (Willis) Russell and L. L. (Butch) Gaucher are shown in the High Flux Isotope Reactor control room with shift technical operator L. J. (Tom) Ledford (standing at right).

The JASPER experiments are scheduled for completion at the end of FY 1992. A field-work proposal has been submitted covering continued operation in FY 1993 in support of the New Production Reactor (NPR) Program and ANS projects. The needs of these and other programs are being reviewed; potential users are being encouraged to make firm commitments as soon as possible. The NPR Program's need for TSR-II experiments depends on the Gas-Cooled Reactor being the choice for the NPR. In addition, cost estimates on the following options are being developed for presentation to DOE: (1) continued operation, (2) standby, and (3) proceeding promptly to shutdown. As with HFIR, one of the key objectives of the TSR-II has been to work toward increasing its availability as a research tool to serve the users better and to facilitate their planning. The TSR-II's excellent performance record in FY 1991 reflects attainment of such.

A decision was made by the DOE Office of Energy Research to shut down the HPRR, which has been on standby since March 1987. Although users with pressing needs for the reactor were identified, approximately one-half of the financial support needed for restart was located, and a business plan was developed based on cost-recovery operation after restart, sufficient programmatic resources to support all restart costs were not evident, and a safeguards and security initiative necessitated movement of fuel-bearing components to storage where standby costs could be reduced.

The BSR has been on standby for over 4-1/2 years. If state-of-the-art equipment could be installed, the reactor would be an excellent training facility. A DOE decision regarding restarting the BSR is pending.

At CEF (also on standby), extensive cleanup and refurbishment have been completed. A technical review indicates it is unlikely that the facility will be required in support of HFIR operations. A final decision regarding the future of the CEF is expected by September 1991.

A decontamination and decommissioning plan has been submitted to DOE for the ORR, which is already shut down and defueled. DOE approval of this plan is expected by September 1991. Extensive decontamination and elimination of surplus materials and hardware have been carried out, and transfer to the Surplus Facilities Materials Program is expected in FY 1993.

Continuation of active support for the development and construction of the ANS, which will ultimately replace HFIR, is an additional and significant mission for Reactor Operations.

A new initiative has been proposed to DOE for establishment of a Center for Excellence in Research Reactors (CERR) to help alleviate a serious national dilemma caused by the decline in the number of research reactors in the country and by an increasing need for such facilities. The CERR would match users with available research reactors.

Plans call for a continuation of an active leadership role in the Association for Excellence in Reactor Operations formed by operators of DOE Class A reactors to enhance safe, secure, and environmentally sound operations and total quality performance by promoting excellence in all phases of operations.

Changes in the nature and level of work involved in Reactor Operations have been dramatic as the transition has been made from all ORNL research reactors having been shut down to operating two reactors and determining the feasibility of restarting others as well as bringing additional reactor facilities back into use. Basically, the effort applied to restart activities has been redirected to achieving excellence in operating the restarted reactors.

Perhaps the most dramatic change that has occurred has been in the "culture" or attitude and work environment created by people at all working levels. A major commitment has been made to continuing to upgrade this culture. Another significant change has been in the evolution of additional requirements for more prompt, more thorough, and more detailed reporting of events to DOE. Resources dedicated to fulfilling these requirements have increased, and efforts have been intensified to provide prompt, factual reports that are in compliance with DOE regulations and to assist DOE in interpreting reactor events.

In accomplishing the restart of HFIR and TSR-II, some important lessons were learned and some notable achievements took place. Sharing the knowledge gained has become a part of the Reactor Operations role.

"Lessons Learned" briefings have been given to many organizations both within and outside of Energy Systems. The Research Reactors Division Quality Assurance Program has been cited on more than one occasion as one that could be drawn upon in planning thorough commitments to quality assurance, and the HFIR itself has been designated as a "model facility" for Energy Systems. Additionally, RRD's training and accreditation programs have helped to provide a road map for other ORNL divisions and programs and other DOE contractors; the system for tracking reactor operations commitments has been tailored to fit the needs of many other organizations and has been used in planning of a central Energy Systems commitment-tracking program; the measures taken to control radioactive contamination at ORNL have been modeled on those in use for HFIR; and the system used in the document-control center has likewise been applied to fit the needs of many other DOE programs carried out by Energy Systems.

The current mission of Reactor Operations is to ensure, through management leadership and controls, that the lessons of the past are not repeated and to strive to be the best of DOE's reactor operating contractors. One of the many management tools used to measure progress is a system of performance indicators, which is carefully monitored on a monthly basis. Utilization of applicable nuclear industry standards will also continue.

Planning exercises have identified 22 strategic issues and action items, each of which is detailed in the Research Reactors Division's strategic plan. Included are a marketing plan for promotion of reactor capabilities, a funding plan for anticipated capital improvements, and a long-term plan for fuel-shipping casks.

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 the DOE, the DOD, NASA, and other sponsors.

RISP addresses R&D goals for extending human senses and dexterity into unstructured and/or semistructured 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.

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 and remote mockup demonstrations for the Burning Plasma Experiment and remote system planning support for the ITER, a planned cooperative effort among the United States, the European Community, and Japan. In addition, 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, and decontamination and decommissioning.

A new activity for FY 1992 will be in robotic development for DOE activities in support of the Space Technology Initiative.

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. Development of advanced material-handling vehicles with increased soldier efficiency through man/machine synergy is being investigated in the All-Terrain Lifter, Articulated System Program for the U.S. Army Belvoir Research Center. 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.

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, the 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 (i.e., 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 The Radiation Shielding Information Center (RSIC) was established in 1962 at ORNL. Founded to serve as an information analysis center (IAC), RSIC follows guidelines and goals suggested by the Weinberg Panel of the President's Science Advisory Committee, which recognized the important role that IACs 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 (i.e., AT—Magnetic Fusion, AF—Nuclear Energy R&D, AH—Remedial Action and Waste Technology, AJ—Naval Reactors, CD—Uranium Enrichment, DB—Nuclear Waste Fund, and GB—Weapons Activity); 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. CDIAC's *Carbon Dioxide Newsletter* reaches 4600 researchers and decision makers in 140 countries. CDIAC is sponsored by DOE's Carbon Dioxide 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 Remedial Action Program (RAP) Data and Information Management System (DIMS) The ORNL RAP DIMS was established in 1985 to support compliance with state and federal

regulations mandating corrective actions at sites contaminated with radioactive and/or hazardous wastes. DIMS consists of three components: (1) the Bibliographic Data Base, (2) the Records Control Data Base, and (3) the Numeric Data Base. The Bibliographic Data Base and associated hardcopy reference collection serve as an index and repository for publications pertinent to the program. The Records Control Data Base serves as an index for retrieval of unpublished information generated by the program such as correspondence, project plans, field notebooks, and chain-of-custody records. 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 RAP, ORNL will play a key role in developing a consolidated data base for environmental data associated with remedial-action activities at all Energy Systems facilities.

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 the Surplus Facilities Management Project, the Formerly Utilized Sites Remedial Action Project, and the Uranium Mill Tailings Remedial Action Project. 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.[2] 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 1990, EMIC has indexed more than 74,000 papers reporting on more than 22,000 chemicals.

In 1979 the U.S. 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 4000 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, the National Institute of Environmental Health Sciences, and the Agency for Toxic

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[2]*Nuclear Facility Decommissioning and Site Remedial Actions*, ORNL/EIS-154, Vols. 1–10, Martin Marietta Energy Systems, Oak Ridge Natl. Lab., 1980–1989.

Substances and Disease Registry; 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.

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. A PC version of selected information from the mainframe file has been developed and is currently being tested within the OHEA. This multifunctional data base will provide EPA scientists and managers with administrative and chemical-tracking information, raw experimental data, and evaluated values of risk assessment parameters to facilitate the process of chemical regulation.

Human Genome Management Information System The Human Genome Management Information System (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 electronic bulletin board, 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 1989–90. The work of the HGMIS has provided DOE's Office of Health and Environmental Research 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*. In addition, *Radon Research Notes*, in support of the DOE Office of Health and Environmental Research, Radon Research Program, has been initiated.

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.

Work for Others

Currently, the work undertaken by ORNL 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 programmatic office. In addition, WFO accounts for an increasing proportion of the Laboratory's R&D effort (Table 5.31). In light of these developments, the Laboratory has placed a new emphasis on management and coordination of WFO. In January 1990 a new programmatic office for WFO was created to coordinate these broad-ranging efforts more efficiently and to develop new WFO projects while ensuring that work is consistent with ORNL's DOE missions and augments ORNL's research capabilities. In 1990 considerable improvement in the coordination of the overall WFO effort at ORNL was achieved.

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: (1) to provide a communications link between upper management and the research staff performing work for non-DOE agencies, (2) to develop solutions to WFO problems that may arise either at DOE or from within the Laboratory, and (3) to develop and to facilitate the growth and expansion of the WFO Program to better complement the Laboratory's DOE missions.

In this last capacity the committee has been reviewing ten candidate ideas for what euphemistically are called "big bear" projects. The "big bear" project is defined as involving interdisciplinary research cutting across several divisions and generally scoped at a level of > $10 million per year. Of the ten ideas proposed, the five selected for further consideration are

- The Bioprocessing Technology Development, Demonstration, Test and Evaluation Center. This candidate "big bear" project involves the establishment of a chemical technology facility that would allow for the full-scale modeling of proposed waste-management technologies. This center would provide federal agencies and industry with the ability to scale up from bench models for evaluating potential commercial applications.
- The Industrial and Municipal Waste Management System. This concept involves

Table 5.31 Work for Others Program resource summary
($ in millions—BA)

	1990	1991	1992	1993
Federal Organizations				
Nuclear Regulatory Commission	17.2	15.1	18.0	16.9
Department of Defense	45.8	40.6	58.5	65.8
National Aeronautics and Space Administration	1.9	5.7	7.8	7.0
Department of Health and Human Services	4.8	3.7	5.3	5.5
Environmental Protection Agency	3.8	1.6	3.1	3.1
National Science Foundation	1.0	1.1	1.1	0.8
Federal Emergency Management Agency	2.2	1.8	2.2	2.4
Agency for International Development	1.3	1.5	2.0	2.3
Other federal agencies	3.3	6.3	6.3	6.9
Nonfederal Organizations				
Electric Power Research Institute	2.9	2.2	1.9	0.7
Other nonfederal organizations	3.0	9.3	4.4	4.7
Total	**87.2**	**88.9**	**110.6**	**116.1**

performing applied R&D to develop a totally new system and infrastructure for managing municipal and industrial waste using advanced separation and processing technologies.

- The Intelligent Vehicle/Highway System. This proposed project involves applying both artificial intelligence techniques and new microprocessing technologies to develop a new technology to deal with the ever increasing congestion on the nation's highways.
- 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 use 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 and Eastern European 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 will be driven by the changing research needs at the national level.

A report on current and proposed WFO projects for the next 5-year planning period follows. The text is organized by sponsor or agency. These WFO technical projects are consistent with the DOE mission and the programmatic objectives of the Laboratory. A significant portion of the ORNL WFO Program involves collaborative work with DOE programs. Several of the Laboratory initiatives (see the "Summary of Major Initiatives" section) involve support from other federal agencies or nonfederal sources.

In 1988 the Oak Ridge K-25 Site's Applied Technology Division (ATD) joined the Laboratory to combine ATD's materials and manufacturing and measurement technology strengths with related technology development strengths at ORNL. The ATD had been charged by DOE UE to transfer technology from the UE Program to other federal agencies (e.g., the DOD and NASA) and to the private sector. Examples of technologies being transferred include polymeric composites; remote/noncontacting precision measurements using lasers and fiber optics; high power-to-weight ratio motors and generators with the associated power and electronic control systems; high-speed centrifugal separation for isotope enrichment, gas purification, and gas detection; reliability and life prediction and assessment; and manufacturing science and technology. A major initiative is aimed at reducing the cost and characterizing thermoplastic materials for space and aircraft application for the Air Force materials laboratory.

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. 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 towards structural and component safety issues, structural aging research, reactor operational data analysis, advanced instrumentation and diagnostics, accident sequence analysis, and license extension requirements. Continued restrictions on the total research budget at NRC Headquarters have resulted in time extensions for some programs and increased cooperative research with other countries in areas such as severe core-damage accident research. ORNL funding from NRC has increased somewhat during the past 2 years and is expected to remain reasonably stable or to

increase over the next several years. Some of the budgetary increases should occur as the NRC undertakes design certification for advanced reactors (e.g., advanced light-water, liquid metal-cooled, HTGR, CANDU, and passively safe reactor designs). Environmental issues will also remain an important area having potential for increased research.

ORNL performs work primarily for four offices within the 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 and Safeguards (NMSS). The RES, the major sponsor of ORNL activities, conducts comprehensive research programs that lead to regulatory guidelines and standards issued by the commission. The NRR is charged with implementing regulations dealing with licensing and inspection of the commercial nuclear industry. These regulations are based primarily on knowledge obtained from the research programs. The AEOD collects, analyzes, and evaluates operational safety data to identify areas requiring NRC or industry action. The NMSS is charged with overseeing public health and safety licensing activities in the nonreactor nuclear arena.

Nuclear Regulatory Research During the next decade 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 including research into the aging characteristics of plant components. The work has contributed new technologies for nondestructive evaluation of nuclear plant piping and valves, and some of these developments have been licensed to several private-sector companies. Another effort is developing both a structural aging handbook and a materials property data base that will provide NRC license reviewers and licensees with a basis for identifying and evaluating degradation processes for concrete structures as well as data on relevant structural assessment methodologies and safety margins (Fig. 5.17).

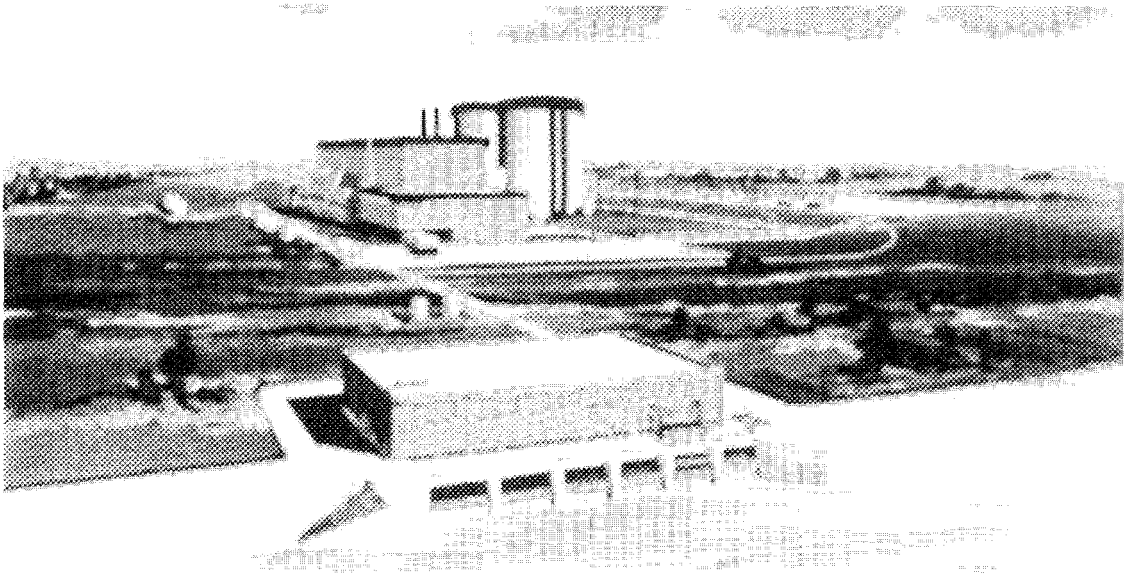


Fig. 5.17. ORNL is evaluating the concrete materials in vital support, shielding, foundation, and containment structures of nuclear power plants under the Nuclear Regulatory Commission's (NRC's) Structural Aging Program. The work will assist the NRC in establishing criteria for demonstrating continued safe operation at or beyond the nominal 40-year design life of a light-water reactor plant.

Research on fission product behavior in severe accident conditions has decreased somewhat, but important research at ORNL continues to help resolve regulatory issues in this area. ORNL work during the past year has provided a basis for possible modifications of the portions of NRC Regulatory Guides 1.3 and 1.4 that deal with iodine chemical forms in containment (Fig. 5.18). Effects in this area are expected to continue at a modest level for several years.

Other research initiatives at ORNL contribute to the NRC's Severe Accident Research Plan. These efforts include work on Boiling-Water Reactor (BWR) core-melt progression and in-vessel strategies for addressing potential severe accident conditions. ORNL staff members collaborate with Sandia National Laboratory and Idaho National Engineering Laboratory 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 the Federal Republic of Germany (CORA-BWR experiments) and with seven foreign nations to develop and to validate computer codes for modeling fission product behavior and core-melt progression under severe accident conditions (i.e., VICTORIA code development by the Cooperative Severe Accident Research Partners).

The Heavy-Section Steel Technology (HSST) Program, which was recognized by the NRC in 1990 for 25 years of continuous outstanding research accomplishment, is the NRC's largest and longest-running research program. In 1989 this NRC research effort to resolve issues and to develop standards relating to reactor pressure-vessel integrity was reorganized into two programs: the HSST emphasizing fracture mechanics testing and standards development research and the Heavy-Section Steel Irradiation Program emphasizing irradiation effects on structural steels. ORNL staff members are providing materials embrittlement data through irradiation and testing of low-upper-shelf weld materials from laboratory heats and from

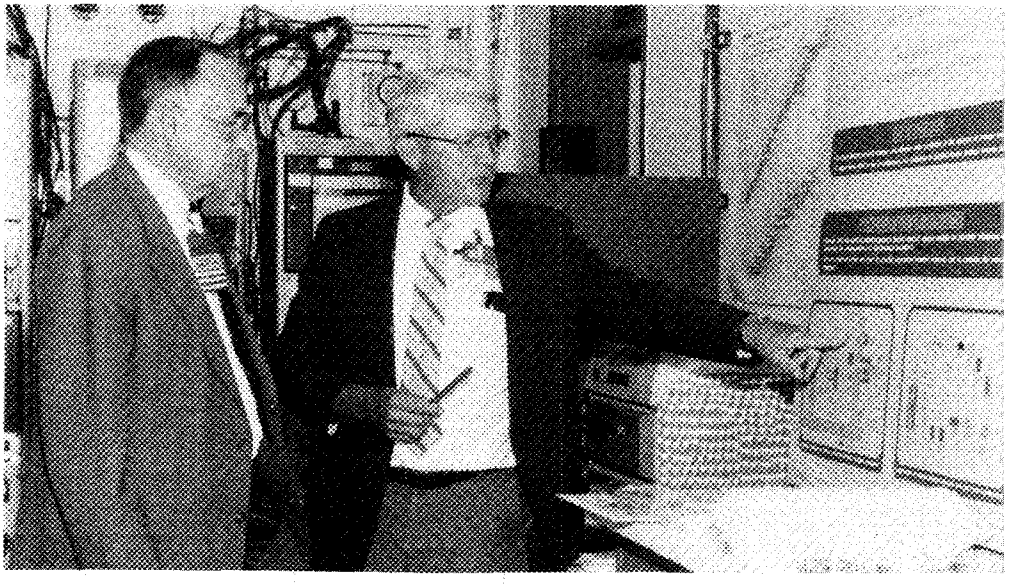


Fig. 5.18. During his visit to ORNL in October 1990, Kenneth Carr, chairman of the Nuclear Regulatory Commission (NRC), was briefed by J. T. Bell, Chemical Technology Division, on fission-product release studies conducted by ORNL. This work is currently providing data as a basis for possible modification of NRC Regulatory Guides 1.3 and 1.4 dealing with chemical forms of iodine in nuclear plant containment during potential severe accident conditions.

actual reactor vessels (e.g., the Midland Nuclear Plant). This work should continue to have high priority at the NRC as a basis for life-extension and nuclear safety regulatory standards. A companion project continues to monitor, to compile, and to interpret data in a national irradiation-effects surveillance data base. Pressure vessel investigations are expected to expand during FY 1992 to include long-term creep-rupture studies for the high-temperature reactors (e.g., LMRs and HTGRs) and supplemental pressure vessel safety research for LWR designs (Fig. 5.19).

ORNL is also assisting the NRC with the development of a generic environmental impact statement (GEIS) appropriate for license renewal rulemaking. This work is currently one of the NRC's major initiatives, and the project team recently received a letter of commendation from E. S. Beckjord, director of the NRC Office of RES, for their work in completing the > 1000-page draft GEIS.

The NRC is continuing to sponsor safety review studies of HTGRs. ORNL provides support on MHTGR thermal hydraulics code validation, assessment of accident evaluation methodologies, and fuel reliability studies. As the NRC extends its considerations of other advanced reactor designs, ORNL's support efforts are expected to increase. New projects anticipated for FY 1992 include safety-related assessments of the CANDU-3 reactor in support of certification, assessments of advanced digital instrumentation and control systems, material studies, and severe-accident analyses.

New ORNL projects for the RES will be under way in FY 1991 and FY 1992 in the areas of

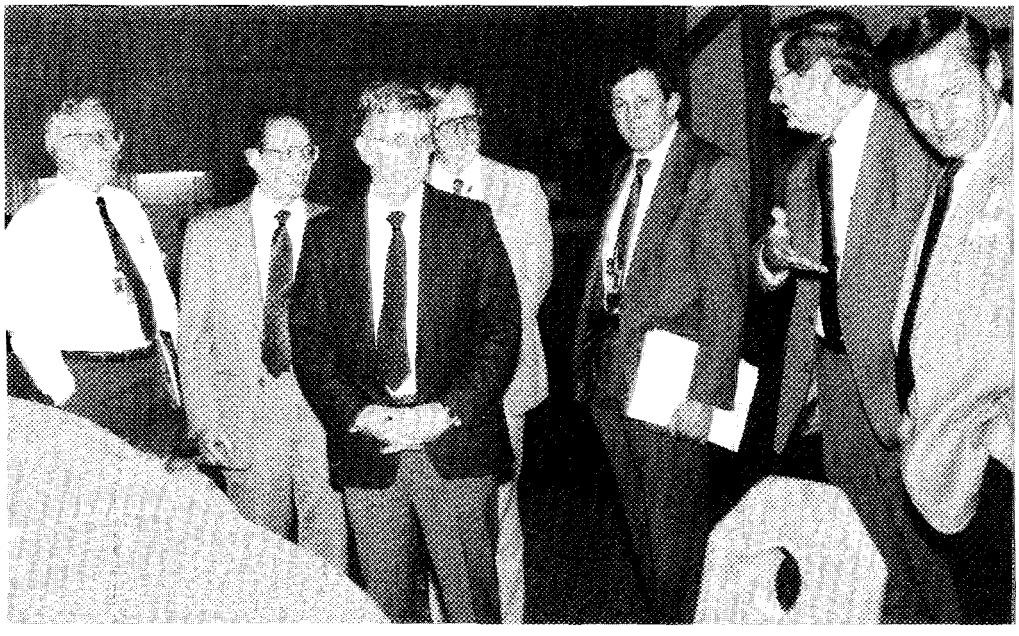


Fig. 5.19. Branch Chief Z. R. Rosztoczy (second from left) and section managers of a newly organized Advanced Reactors Branch of the NRC Office of Nuclear Regulatory Research (NRC/RES) are shown viewing reactor pressure vessels tested in ORNL's Heavy-Section Steel Technology Program laboratories. ORNL staff members provided information on research and development needs for various advanced reactor concepts and the capabilities of U.S. Department of Energy national laboratories (including ORNL) for meeting those needs. Shown in the photograph are (from left) M. H. Fontana (Engineering Technology Division), Z. R. Rosztoczy (NRC/RES), R. O. Meyer (NRC/RES), W. B. Hardin (NRC/RES), T. S. Kress and A. J. Szukiewicz (NRC/RES), (Engineering Technology Division), C. E. Pugh (Director of NRC Programs at ORNL)

human factors research and evaluation, acceptance criteria for electromagnetic interference in digital instrumentation and controls, and review of radioactive transport specification packages.

The journal, *Nuclear Safety*, coordinated by ORNL staff, received recognition in 1990 by DOE director, Admiral Watkins, for completing 30 years of publication in the nuclear safety arena. NRC Chairman Kenneth Carr also sent a congratulatory letter and praised the publication for "outstanding contributions to the development of safety standards in the entire nuclear industry." Further evidence that the journal's tradition of excellence in safety research publications continues was provided by an "Award of Excellence" received by *Nuclear Safety* editor, E. G. Silver, in the 1991 Publications Competition sponsored by the East Tennessee Chapter of the Society for Technical Communication. Publication support is expected to continue.

Analysis and Evaluation of Operational Data AEOD's mission within the NRC is to serve as the focal point for the continuing independent assessment of operational performance of commercial 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 probabilistic risk methodology to determine the quantitative significance of these events.

Among active projects for AEOD ORNL is (1) providing support to assist in the resolution of operational performance issues, (2) benchmarking the operating track 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 occurring at plants—the Sequence Coding and Search System (SCSS). Used to construct event sequences, the SCSS is a highly structured system that supports detailed searches of operational occurrences. Other data systems are maintained on (1) foreign reactor events, (2) international incident reporting, and (3) nonreactor events. ORNL also provides extensive support to the AEOD on the NRC's Performance Indicator (PI) Program by evaluating events as to their cause. ORNL is also assisting in the development of new indicators for the NRC. The PI Program is designed to monitor changes in plant performance and to indicate corrective actions needed before plants develop serious problems.

Nuclear Reactor Regulation Using expertise developed in its programs for the RES and others, ORNL provides technical consultation and assistance to the NRR. On-call assistance is currently provided in the interpretation of nondestructive 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. During FY 1991, work for the NRR has increased in scope and funding to include analyses of potential accident sequence precursor events occurring during low-power or shutdown operations, evaluation of materials irradiation test data, and water chemistry standardization for nuclear power plants. The increase in NRR work is expected to continue during the next few years to support NRC considerations of applications for nuclear plant license extension and certification of advanced reactor designs.

Nuclear Material Safety and Safeguards The NMSS sponsors several projects at ORNL including licensing assessments for fuel enrichment facilities, computer programming and documentation for criticality safety, and shielding and thermal analyses of nuclear fuel facility and package designs. The ORNL initiative in the area of licensing enrichment facilities was begun late in FY 1989 and will continue beyond in FY 1991. The activity to review terminated materials license files that began in FY 1990 also will continue beyond in FY 1991. This activity will help the NRC ensure that radioactive materials–handling facilities with terminated licenses were properly decontaminated and pose no threat to public health and safety. Another new project in FY 1991 provides technical support in reviewing the design, construction,

operation, and performance of low-level waste facilities. In FY 1991, ORNL staff members also began assisting the NMSS in developing a national profile on commercially generated low-level radioactive mixed waste. A new project expected to begin during FY 1992 will provide 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. 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 the implementation of inventory verifications, the analysis of special nuclear materials samples, the preparation of site-specific materials standards, and the review of environmental assessments and operating procedural changes.

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, the Strategic Defense Initiative Office, and the U.S. Transportation Command. Several projects are managed by non-ORNL Energy Systems organizations (see the "R&D Contributions for WFO Managed by Other Oak Ridge Facilities" subsection), 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 those Army-funded projects, ORNL also has an Army optics development program 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 Laboratory Command (LABCOM) has expanded significantly and now involves the transfer of DOE technologies to several LABCOM agencies. These programs focus on ORNL's unique capabilities in advanced materials and robotics, and they also include basic and applied science. LABCOM has proposed a major initiative to establish a 5-year collaborative research program with all DOE laboratories beginning in FY 1991. Oak Ridge staff have helped provide the leadership in planning this 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 using nondestructive evaluation procedures. 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. Innovative shielding materials and concepts (e.g., microwave sintering ceramics for armor) will be evaluated for the Defense Advanced Research Projects Agency the Tank Automotive Command (TACOM), 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 LABCOM 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 environmental impact statements 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 also assisting the Army in assessing the impacts of destroying the U.S. European stockpile of chemical munitions at the Johnston Island disposal facility. ORNL is also providing support in the development of enhanced response plans for installations that store chemical agents and munitions. For the 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 (TECOM). 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 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 (NGB) is expected to grow moderately over the planning period. ORNL is providing analytical techniques to NGB for force structure and mobilization planning and related civilian missions.

In addition, under the sponsorship of the Military Traffic Management Command (MTMC), ORNL is developing a proof-of-concept prototype, called Integrated Booking System—Prototype, designed for the selection of ocean carriers to move military cargo. ORNL is defining the requirements for a shared data environment for the target Integrated Booking System. In another project ORNL is also designing and prototyping a decision support and executive information system for the MTMC Personal Property Directorate.

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, energy conservation, and waste disposal. 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. ORNL is planning to use the forecasting system to analyze the impacts of democratization of Eastern Europe and relate events.

ORNL plays an important role in instrumentation and engineering R&D for the David W. Taylor Research Center (DTRC). The DTRC is the Navy's primary research, development, test, and evaluation center for naval vehicles. Two primary areas of interest to the DTRC are ship and submarine silencing and methods to design and to test high-strength hulls and components. ORNL assists the DTRC 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.

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 Navy Underwater Systems Center, ORNL will use the injection into microwave plasma 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 analysis research project for the Naval Sea Systems Command.

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 Engineering Services Center (AFESC) 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 AFESC 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 DOD's Installation Restoration Program (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.

For the Wright Research and Development Center (WRDC), ORNL is performing research in multisensor integration (MSI) 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 MSI 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 major facilities of the Tactical Air Command and the Space Command.

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, the U.S. Department of Transportation, and the various defense transportation agencies—linking such WFO sponsors as the Federal Aviation Administration, the Federal Highway Administration, the Military Airlift Command, the Military Sealift Command, the Military Traffic Management Command, and the United States Transportation Command (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, the Military Airlift Command (MAC), Military Sealift Command (MSC), and Military Traffic Management Command (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 (ADANS). ADANS 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 (Fig. 5.20). 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 International Business Machines 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.

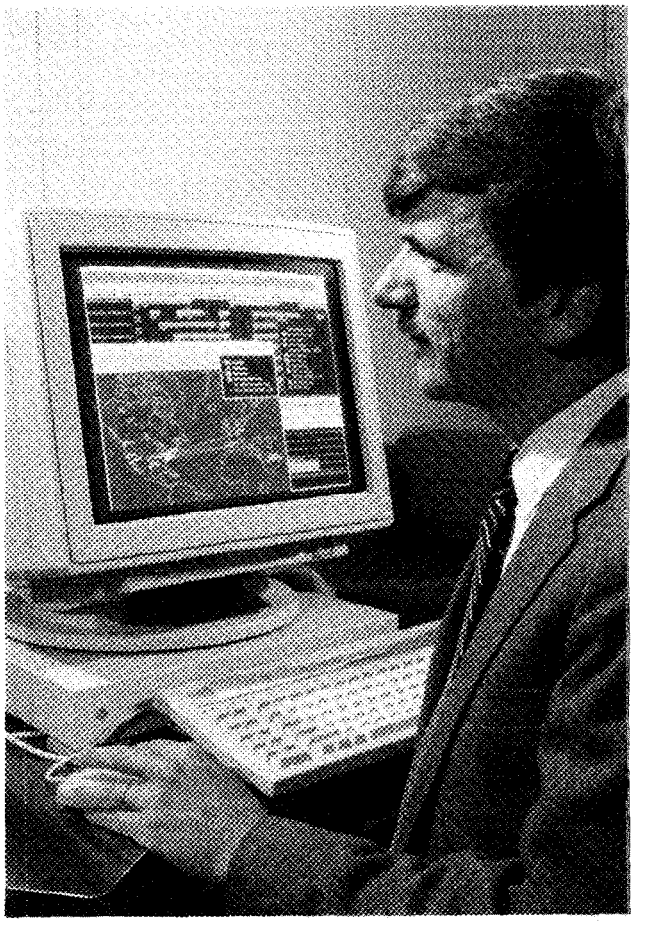


Fig. 5.20. M. R. Hilliard works on an Airlift Deployment Analysis System workstation.

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 in use of networked workstations and personal computers to implement a command-wide "corporate" data base. This 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. In addition, an experiment is in preparation with force-flow cooled, cable-in-conduit conductors to determine the existence of thermal hydraulic quench back or the rapid quench of a superconducting cable under certain conditions of current density, magnetic field, and helium temperature. 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.

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 Bush administration. All indications are that funding cutbacks in the overall SDI program are likely in the future.

Several significant program changes are expected in the next few years in ORNL's SDI research. The SDI Survivable Optics Manufacturing Operations Development Integration Laboratory is a major SDI initiative that expanded in FY 1989 (Fig. 5.21). 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 fabrication, ion implantation, radiation testing, and optical characterization are being applied to the development of radiation-hardened, passive optical components. Figure 5.22 shows one tool used in support of these activities. These components are of interest to SDI and, potentially, to other areas within the DOD. 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.

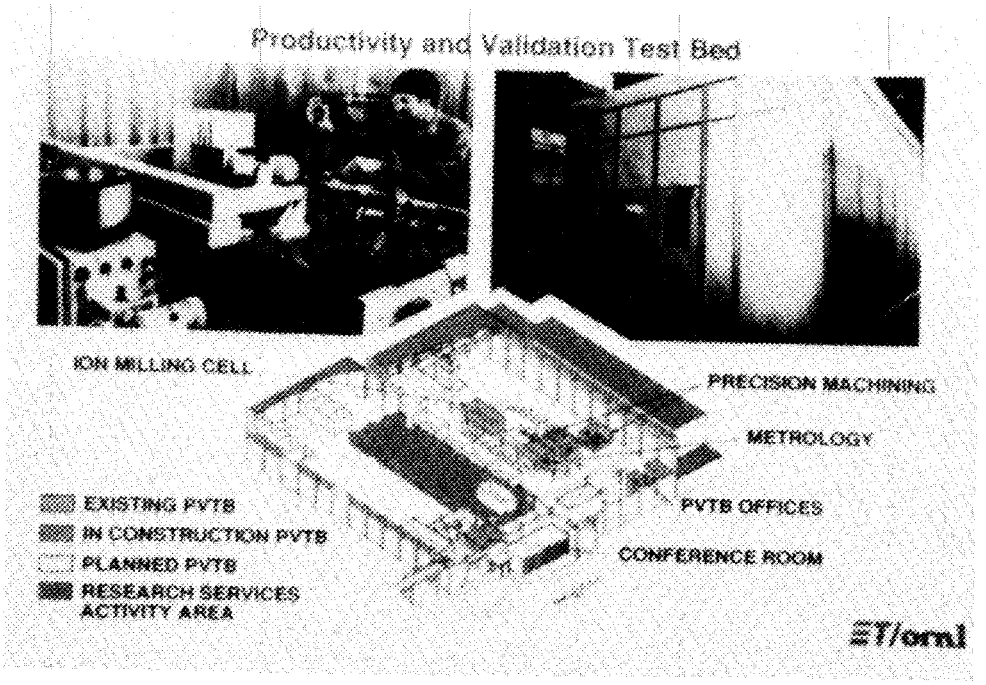


Fig. 5.21. The Manufacturing Operations Development Integration Laboratory is a collaborative concept that includes industry, academia, and federal laboratories in concurrent efforts to reduce manufacturing cost by the infusion of advanced technology at the user level of fabrication.

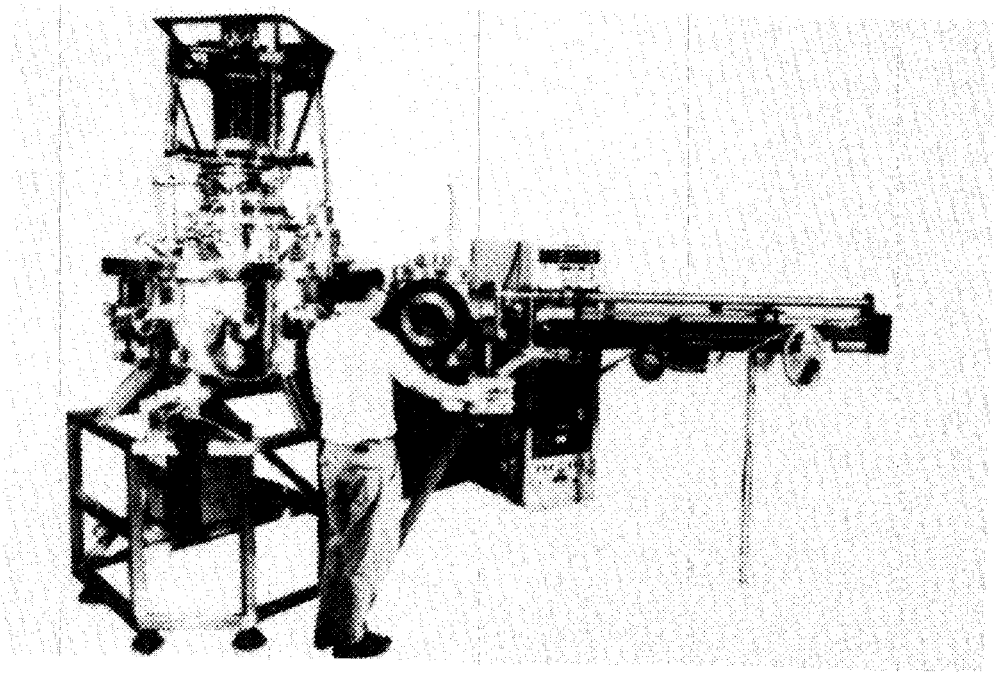


Fig. 5.22. Don James operating the cryogenic scatterometer in the Optics Characterization Laboratory. The cryogenic scatterometer is used to measure light scattering properties of optical components for surveillance satellites under simulated space conditions.

National Aeronautics and Space Administration

Much of the R&D that ORNL performs for NASA is managed by non-ORNL Energy Systems organizations. (See the "R&D Contributions for WFO Managed by Other Oak Ridge Facilities" subsection.) 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 radio-frequency 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 for joint research in mathematical, statistical, and computational methods is expected from NASA's global change program. ORNL is also working with the Tennessee Valley Authority to propose new work under NASA's Freshwater Initiative 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. NASA through the Marshall Space Flight Center supports work on modeling and numerical simulation of binary alloy solidification processes. The level of support for this work is expected to increase somewhat in FY 1991–FY 1992.

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 new initiative, Oak Ridge Participation in Planning for the National Space Program, is included in this section under the "Assistant Secretary for Nuclear Energy" subsection.

U.S. Department of Health and Human Services

The Department of Health and Human Services (DHHS) supports research, in-depth literature evaluation, analysis, and data-base 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 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.

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-a 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 tracheal implant system has made it possible, with NCI funding, to study the effects on tracheal cells of mixtures of agents and sequential exposures at the molecular, cellular, and tissue levels.

For the NIEHS, ORNL is enlarging the data base on the response of germ cells to chemicals. Gene-mutation and chromosome-aberration induction and their organismic effects are investigated, and the molecular and cytogenetic nature of the mutations is analyzed.

The NICHHD supports a project to generate transgenic lines of mice by DNA injection into fertilized eggs.

The NCHGR supports chemically-induced saturation mutagenesis within defined segments of the mouse genome for physical/functional mapping.

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, the National Institute of Child Health and Human Development, 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 addressed numerous health, environmental, and economic problems and issues, particularly research on the ecological effects of global change, toxic effects of pollutants associated with energy-production processes, waste disposal, and methods for environmental monitoring and assessment. Health and environmental risk analysis and 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 on plastics recycling. In addition, work is under way on evaluating various economic incentive programs that might be implemented to promote additional recycling and source reduction of solid waste.

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 joint cooperative research project with the EPA and private industry includes utilizing unique capabilities and facilities for testing thermal materials and systems. 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, which are being phased out as directed by the Montreal Agreement signed by 56 countries 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. These include

- 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 life-time risk assessment).

Data-base development activities for the EPA are expected to increase. CURE, an evaluated data base, 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 Data Base 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 (i.e., toxicity data on more than 22,000 unique chemicals) are being used for the 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 activities will decline in FY 1991 but are expected to increase slightly in FY 1992. Major emphasis is on the effects of acidic precipitation on forest and aquatic systems on ion mobility in soils. New emphasis will be placed on cost-benefit analyses of Clean Air Act–mandated emissions controls.

ORNL will increase its research and analysis support to the EPA's Environmental Monitoring and Assessment Program in the areas of site characterization, biological indicators, landscape pattern analysis, biological markers, environmental risk, and technical integration. Continued support of the EPA's deposition standards (critical loads) research program is also anticipated.

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 data bases 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.

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 1991.

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 the 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 basic research is not supported by DOE programs. Discussions are in progress to assist the NSF in promoting educational training for the sciences. The NSF is supporting 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.

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 streams ecosystems to disturbance. ORNL will continue to explore its potential contributions to the planned U.S. Department of Interior–NSF–DOE interagency Continental Drilling Program. Another research effort sponsored by the NSF involves development of a fiber-optic-based FIS, 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 in Antarctica. ORNL will prepare a programmatic environmental impact statement as well as several site- and project-specific environmental impact assessments. Emphasis is being placed on waste and fuel management, 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.

These programs are expected to remain stable, as shown in the resource projections, at levels that reflect current agency guidance.

Agency for International Development

ORNL serves as a center of expertise for the Office of Energy's AID on technical aspects of energy planning and energy technology applications for developing countries; emphasis is on global energy efficiency improvement and environmental management. ORNL's work includes research, analysis, and information dissemination. In addition, ORNL provides technical assistance in the following areas:

- project development,
- implementation planning,
- evaluation related to energy planning,
- renewable energy technologies, and
- environmental impacts of climate change.

A proposed initiative, Energy Technologies for Developing Nations (Including Eastern Europe), is included under the "Other DOE Programs and Installations" subsection in this section.

U.S. Department of Transportation

ORNL's Center for Transportation Analysis, funded by the U.S. Department of Transportation, 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 the Federal Highway Administration (FHWA) in research areas that include development of freight and passenger demand models; assessment of data quality and data consistency of highway statistics; design of sampling models and estimation procedures to provide needed information for policy formulation and policy impact studies; 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 inter-modal 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 type, 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 the DOD, ORNL has been the leader in the development of an extensive national highway network data base 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 viewpoints 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.

In a cooperative venture with FEMA and the 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 (FAA) 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 FAA, by virtue of its extensive R&D work for the Military Airlift Command.

U.S. Department of the Interior, Bureau of Mines

ORNL is developing some innovative resource-modeling techniques for the Bureau of Mines that

will be used to study the relative competitiveness of the U.S. mineral industry, the impacts of acid rain legislation on the minerals industry, and the economic impacts of the development of advanced materials.

U.S. Department of the Interior, Bureau of Reclamation

A renewed interest in seawater desalination has been demonstrated in currently discussed legislation that will result in an initiative funded in the Bureau of Reclamation beginning in FY 1992. An 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 assistance to the National Oceanic and Atmospheric Administration of the U.S. Department of Commerce. The Coast Watch Program has focused on the Eastern seaboard and especially on the Chesapeake Bay. Current work will provide land cover classification and change detection for two additional time periods based on more detailed satellite imagery for the entire Chesapeake Bay. Its purpose is to establish a base of knowledge and experience for the national Coast Watch effort and to provide wetlands data to the user communities including the Coastal Oceans Program and Chesapeake Bay Program. This effort will progress in tandem with workshops to develop protocols and to initiate the national Coast Watch effort.

ORNL is helping the U.S. Department of Commerce, Bureau of the Census, plan the year 2000 census by assisting in managing changes in technology. Upcoming work in this area will focus on automating year 2000 census field offices.

Other Federal Agencies

ORNL also provides technical support to a variety of other federal agencies including the Consumer Product Safety Commission. We also anticipate collaborative work with the U.S. Department of Agriculture (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 UNESCO, and we expect this support to continue. ORNL will assist 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 the Tennessee Valley Authority. ORNL provides support to the Bureau of Labor Statistics in artificial intelligence systems to provide estimation of consumer prices index and survey decision. Finally, new work is anticipated in support of the Office of National Drug Control Policy and its various support agencies

Nonfederal Organizations

Electric Power Research Institute

The 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,
- delimiting the relative importance and effects of wet and dry deposition of acidic substances in both forest and agricultural systems,
- developing a mechanistic and predictive forest-cycling model to address potential future impacts of atmospheric deposition,

- 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, and
- exploring theoretical aspects of uncertainty.

The Laboratory expects to continue these and other programs for EPRI during the course of the planning cycle. ORNL is completing work on acid-deposition effects on agricultural and forest systems. 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. In addition, a new project on the role of vegetation in remediating waste sites has begun.

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.

EPRI is currently co-funding 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 reactor 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 liquid-metal and modular gas-cooled reactor 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.

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 materials and products that are economically feasible, durable, and free of CFCs for increasing energy conservation in residential and commercial buildings. Agencies include the National Roofing Contractors Association, the Polyisocyanurate Insulation Manufacturers Association, and the Society of Plastics Industry.

ORNL has entered into a cooperative research project with Attic Seal to test convective heat losses in some types of attic insulation and to measure the effect of convective retarders to restrict this energy loss in residential building.

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 Umweltbundesamt,
- 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, and
- the Center for Indoor Air Research.

R&D Contributions for WFO Managed by Other Oak Ridge Facilities

ORNL will continue to provide scientific and technical support to WFO programs that are managed by the Energy Systems Applied Technology Organization; these include the Space and Defense Technology (SDT) Program, the International Technology Program, the Data Systems Research and Development Program (DSRD), and HAZWRAP. Generally ORNL will take part in the R&D aspects of these programs and not in the development and implementation phases of the work except in the technology transfer function. These efforts will be coordinated by central staff programs.

Space and Defense Technology Program

The mission of the SDT Program is the application of Energy Systems' special and unique research, development, and prototype fabrication capabilities for the purpose of solving problems germane to national defense and space exploration. In this effort the SDT Program utilizes the diverse and multidisciplinary capabilities of the Oak Ridge sites. In addition, maintaining and expanding the current knowledge base for future DOE missions and transferring technology to other federal agencies and the private sector are important aspects of the program.

ORNL currently provides approximately 60% of the total SDT Program support to the DOD and NASA. The ORNL project areas include applications of materials technology, robotics, development of unique data acquisition and analysis systems, environmental effects, optics development and precision mirror manufacturing technology, and energy storage systems.

Data Systems Research and Development Program

The mission of the DSRD Program is the design, development, and application of state-of-the-art information technologies that provide modern solutions to problems affecting mission performance of DOE and other federal agencies. Through program management, research, development of unique systems, and design of prototypes for advanced information systems, advanced computer techniques are committed to the solution of important national problems. Technology transfer is included as an integral component of the DSRD Program through effective and innovative hands-on applications. The overall DSRD Program provides centralized direction for data systems development and related work including research, applied research, program management, and selected applications.

ORNL provides support for the DSRD Program and is assigned the DSRD work that requires the unique research capabilities of the Laboratory. Examples of DSRD research areas to which ORNL contributes include

- expert systems and decision support,
- enhanced data acquisition,
- simulation and forecasting,
- advanced parallel architecture design,
- measurement sciences,
- advanced computing systems support,
- logistics systems development,
- statistical and numerical methods, and
- raining simulators and their design.

Some of the DSRD projects to which ORNL contributes include a simulator sickness project and design of Navy financial systems using artificial intelligence design and control programs.

Hazardous Waste Remedial Action Program

The varied and complex waste issue at Oak Ridge, which concerns low-level and other radioactive waste, hazardous waste, and mixed waste, has resulted in a large and growing R&D effort and level of expertise in waste treatment and characterization. Examples of technical efforts include solidification of waste forms, various destruction techniques for hazardous organic chemicals, exotic detection methods, in situ treatment technologies, and modeling capabilities. Experience in addressing these problems is in high demand by the DOD and other federal agencies, and this work aids in developing technologies to be used by the DOE. The work is likely to grow in importance in the next few years.

Energy Systems is currently doing hazardous waste work for other federal agencies in two major areas: technical support and technology development. Energy Systems provides technology support to the various EPA regions and for the EPA Hazardous Waste Engineering Research Laboratory by reviewing proposed technologies and collaborating on technical problems. The Air Force Engineering Services Center, the Navy Energy and Environmental Support Activity (NEESA), and the Army Toxic and Hazardous Materials Agency all use ORNL researchers. HAZWRAP is also active in site characterizations for various federal sponsors.

Technology development is currently provided to the Air Force Engineering Services Center, NEESA, and the EPA. Projects include removal of volatile organics from soil and groundwater, separation of heavy metals from sand, fixation of hazardous waste in stable forms, development of water cleanup methods, and stabilization of heavy metals. This area is growing rapidly and will continue to expand over the next several years.

Laboratory-Directed R&D Program

The principal objective of the ORNL Exploratory Studies 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 5000.4, "Laboratory Directed Research and Development," dated February 28, 1991.

There are two major activities within the Exploratory Studies 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 1991 budget was $9.0 million for the ORNL program. The budget allocated by the ORNL Executive Committee was $7.4 million; $1.8 million was allocated for the Seed Money Fund, and $5.6 million was allocated for the Director's R&D Fund. This total amounts to approximately 1.4% of the total operating budget for ORNL. Table 5.32 lists authorized funding for FY 1990–FY 1993 (projected).

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 through line management; most are selected by the Laboratory's Executive 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 exploratory funds maximizes the likelihood that novel and seminal ideas originating from the staff will be recognized and supported.

Table 5.32. [illegible]

	Fiscal year			
	1990	1991[a]	1992[b]	1993[b]
Total funding	9.0	9.0	10.0	12.0

[a]$7.4 million allocated.
[b]Estimated.

The Exploratory Studies 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. Additional descriptions of ORNL's Exploratory Studies 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 Exploratory Studies Program.

6. environmental, safety, and health management

6. Environmental, Safety, and Health Management

Oak Ridge National Laboratory (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 operations at the Laboratory. Changes in culture and organization have occurred and are permeating all aspects of operations. Key activities have been identified that will move ORNL forward in its goals of excellence in ES&H activities.

ES&H Organization

The operating structure of the Laboratory has evolved over the years along with its evolving research and development (R&D) missions. The appointment of a new laboratory director in January 1989 was soon followed by changes to the ES&H structure in October 1989. To enable ORNL to respond more effectively to challenges arising from ES&H issues, the new Environmental, Safety, and Health Compliance (ES&HC) Directorate and an ES&H Coordination Committee were formed. The coordination committee will provide better communication and coordination of tasks among organizations involved in ES&H activities. It is chaired by the deputy director and consists of senior ES&H managers, five members of the Executive Committee, and the chairperson of the Division Director Caucus. This provides top-level management overview of this vital area.

Most ES&H and quality assurance (QA) functions have been combined into one organization to strengthen the ability to audit and 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 (WM) and fire protection are located within the Operations Directorate. Figure 6.1 shows the key elements in ES&H management.

Environmental, Safety, and Health Compliance Directorate

The ES&HC Directorate consists of 5 offices: Safety and Health Protection (total staff 73); Radiation Protection (120 staff); Environmental Compliance and Documentation (64 staff); Operational Readiness and Facility Safety (34 staff); and Quality (63 staff). Each office directs the oversight and support for a different facet of compliance and improvement in the operations of ORNL.

The Office of Safety and Health Protection provides the Laboratory with several services in the areas of industrial hygiene, industrial safety, and training. Industrial Hygiene Section personnel work on improving the staff's safety in areas such as hazardous chemical control and asbestos abatement. Industrial Safety Section personnel provide support in traditional worker safety areas such as OSHA requirements and personnel safety programs. ES&H

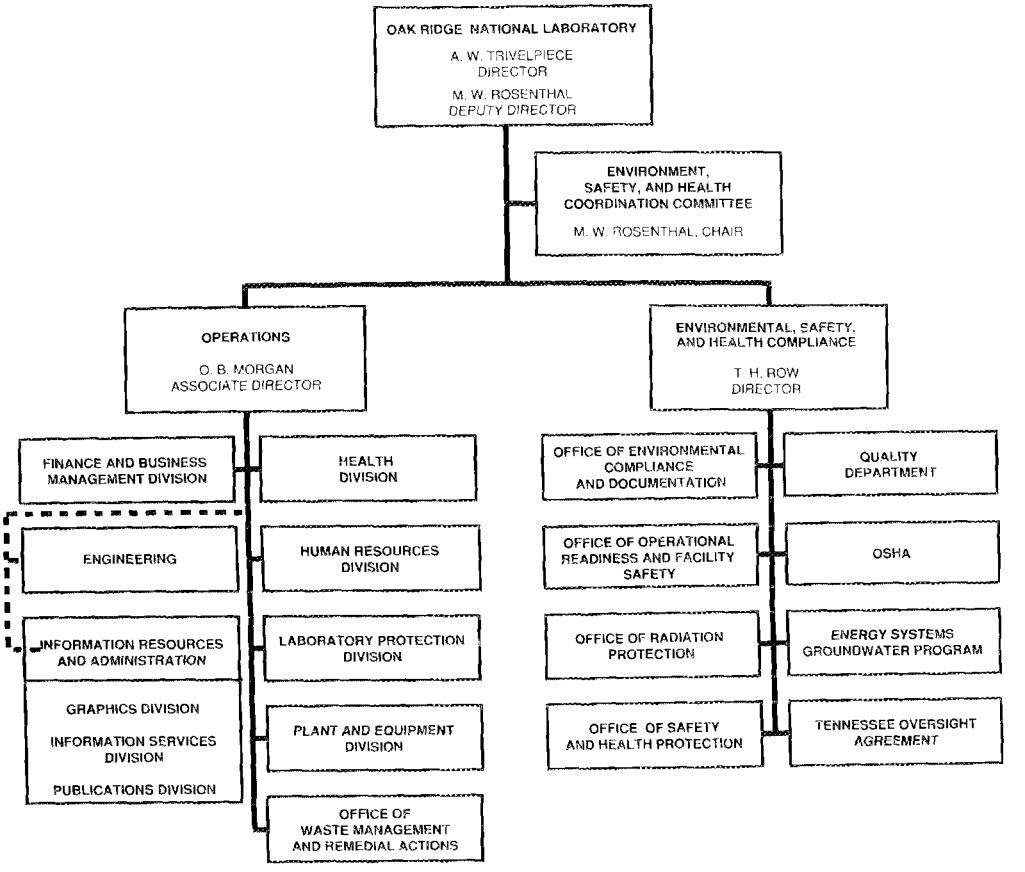


Fig. 6.1. Key elements in ES&H and QA management and support divisions' management.

training programs are developed and implemented by this office. As a special project, this office is developing an integrated resource management system for the ES&HC Directorate.

The Office of Operational Readiness and Facility Safety has responsibility for coordinating the safety analysis review and upgrade program (upgrading all safety analysis documents and operational safety requirements), the independent Director's Review committees (eleven safety committees of technical experts), the Conduct of Operations Program, and the Self-Assessment Program. Also within the office is the Measurements and Assurance Program, which performs surveillances and develops procedures to assure the quality of work within the ES&HD Directorate.

The Office of Radiation Protection is separated into a Radiation Surveillance Section (which provides health physics technicians and performs radiation surveys) and a Radiation Monitoring Section (which has responsibility for personnel dosimetry and bioassay monitoring). The as low as reasonably achievable (ALARA) program for ORNL is also led by this office.

The role of the Office of Environmental Compliance and Documentation (OECD) is to provide environmental guidance, documentation, field verification, and assistance to ORNL divisions and programs. OECD staff assist in the preparation, procurement, and maintenance of required environmental permits and documents; serve as the source of compliance expertise and interpretation; and interact with regulatory agencies. Addressing new or modified regulations and permit requirements is an ongoing high-priority activity within the OECD, as is increasing attention to self-assessment of the ORNL status of compliance with regulatory requirements.

The Quality Department provides the Laboratory with an independent quality review of its operations. Each division is assigned a quality assurance specialist (QAS) who oversees the adequacy of QA plans and procedures. The office also has responsibility for tracking findings and corrective actions from the numerous audits, assessments, appraisals, and surveys that occur throughout the Laboratory. The Quality Engineering and Inspection Section does testing of equipment to ensure safe operations. The Total Quality Management (TQM) Program is also coordinated by this office.

In addition to the offices, there are three ES&H programs within the directorate. The Tennessee Oversight Agreement signed by DOE and the state of Tennessee will allow state environmental inspectors access to all areas of the Laboratory. A program office has been established to provide support and assistance to these personnel. The Occupational Safety and Health Administration (OSHA) Program has responsibility for coordinating ORNL's activities to bring its facilities into compliance in a rapid and cost-effective manner. As a result of the Tiger Team assessment, it was recognized that Energy Systems needed a coordinated groundwater program for the Oak Ridge Reservation. This program has been initiated and reports to the ES&HC director.

Other ORNL ES&H Organizations

Most of the remaining functions that are typically considered as ES&H-related are within the Operations Directorate. These include the Health Division, Laboratory Protection Division, and the Office of Waste Management and Remedial Action (OWMRA). 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 ES&H-related.

Within the Laboratory Protection Division are the Laboratory Shift Supervisors, the Safeguards and Security personnel, the Fire Department, and the Emergency Preparedness office. Each group addresses a different aspect of ES&H in the proper operation of the Laboratory.

The OWMRA's responsibilities are grouped organizationally into two main sets of functions. The first set is composed of 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 P&E Division) as well as facility upgrades and construction of new WM facilities. The second set is composed of remedial-action functions that cover surveillance and maintenance (S&M) of inactive waste sites and surplus radioactively contaminated facilities and decontamination and decommissioning (D&D) of the contaminated facilities. This general organizational grouping is consistent with the organizational structure that has been adopted by DOE Headquarters, the local DOE field office, and Martin Marietta Energy Systems, Inc. (Energy Systems). More details on this organization are provided later in this section.

ES&H in Research Divisions

While ORNL central support organizations provide much of the support for ES&H activities, the research divisions, or line organizations, are responsible for the ES&H activities within their organizations. Divisions are responsible for having all of their personnel properly trained for the functions they perform, ensuring 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. The division safety officer has the responsibility for representing the division director in all safety-related matters. This responsibility includes consultation, safety reviews, design reviews, inspections, safety promotion, and training. The radiation control officer has similar responsibilities in the area of radiation safety. The environmental protection officer is responsible for coordinating the environmental-compliance efforts within the division. The training coordinator helps ensure that all personnel have received the appropriate training. Some of the ORNL divisions have consolidated the above offices into a single section within the division. It is then staffed by full-time personnel to provide line-managed support for

ES&H within the division. The division's QAS, while a member of the Quality Department, is located with the division for assistance and oversight.

A new concept being implemented at ORNL, as at other DOE facilities, is that of the facility manager. Each facility or area within a division is assigned to a person who has responsibility for the activities occurring within it. 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.

Research divisions, as the 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. The division director and his staff work with the support organizations to ensure that ES&H requirements are properly included. Some divisions use a more formal system than others, dependent largely on the levels of hazards involved.

Tiger Team Results

A Tiger Team assessment was conducted at ORNL and the DOE Oak Ridge Field Office (DOE-OR) between October 22, 1990, and November 30, 1990. The assessment was conducted by a team of over 80 specialists from various DOE offices, contractors, and consultants organized into four subteams: environmental, sitewide safety and health assessment, reactors safety and health assessment, and management.

The Tiger Team acknowledged that there has been significant improvement in ORNL's ES&H performance since the release of the secretary of energy's initiatives in June 1989; however, 413 deficiencies were identified in the ES&H program during the review. The environmental subteam identified a total of 70 findings; 43 findings related to nonconformance with ORNL procedures, Energy Systems procedures, DOE orders, or federal or state laws and regulations, and 27 findings in which best management practices were not attained. The sitewide safety and health appraisal identified 202 findings.

No Category I findings (a situation that presents a clear and present danger) were identified. Ten of the findings were Category II findings (a significant risk or noncompliance but no immediate danger), and the balance were Category III findings (a noncompliance or needed improvement). The reactors safety and health appraisal identified 128 findings of which 2 were Category II and the rest were Category III. The management subteam noted 12 management findings and 1 finding related to the self-assessment process. Five noteworthy practices were highlighted during the Tiger Team assessment.

The Tiger Team highlighted a number of other key findings besides the 12 Category II findings from the 2 TSAs. The key issues were also amplified in the secretary of energy's memorandum transmitted with the draft Tiger Team report to various DOE offices. ORNL was directed to pay special attention to management issues, self-assessment, contamination spread, waste minimization, quality verification, and safety programs.

During the Tiger Team closeout, Tiger Team leader John Patterson commented that ORNL is a challenging site because of its multiprogram nature, its size and age, and its historical role in radiochemical processing. The Tiger Team felt that DOE had not been kind to ORNL because the site had been left with legacy problems but without the resources to fix them. However, the Tiger Team determined that ORNL has a healthy environmental program; the reactor program was strengthened by the rigors of restart; and although sitewide progress has been mixed, pockets of excellence exist, and the staff has clearly heard the message regarding ES&H expectations. The Tiger Team hoped that the audit would serve as a catalyst to promote excellence. A challenge was issued to the management of ORNL to sustain the progress that was made.

ES&H Plans and Initiatives

In response to the Tiger Team report, a comprehensive action plan has been prepared that lists actions to respond to every finding. The action plan includes detailed actions, cost estimates, funding sources, availability of funds, and scheduled completion dates. It has gone through five revisions that incorporated comments from Energy Systems, DOE-OR, and the various DOE programmatic offices with responsibility for ORNL activities. The estimated cost for completion of corrective actions is over $1 billion, to be spent over an 8- to 10-year period. Table 6.1 identifies the estimated costs associated with corrective actions to the Tiger Team findings, based on the fourth revision of the plan. Also shown are the current estimates of total ES&H costs. The Tiger Team costs represent only a fraction of the total needed to upgrade the Laboratory's ES&H compliance.

One line of Table 6.1, labeled Operating Legacy Cost, indicates costs are to be determined. ORNL has submitted eleven field-work proposals (FWPs) for FY 1992 and FY 1993 to cover the cost of upgrading the Laboratory's ES&H programs. However, actual funding is expected to be less than requested. The amounts in future years are dependent on the funding levels in these years and on any additional required enhancements to the ES&H program. These FWPs are discussed in more detail in the "Scientific and Technical Programs" section, under "Office of Energy Research."

The Tiger Team expressed concern that the recent improvements would not be carried forward in a self-sustaining pursuit of excellence. They said the capability exists for improvement but that some basic elements of sound management are necessary. To ensure that the momentum is continued, the following seven key management programs are being emphasized:

- Strategic plan for ES&H: a strategic plan for ES&H is under development to provide vision and coherence to ES&H activities. It will integrate with the Energy Systems ES&H Strategic Plan and ORNL's strategic planning efforts. As part of this activity ORNL's goals and objectives for ES&H will be defined and practical strategies developed. In addition, the process for integrating ES&H and R&D activities will be further developed and formalized, based upon a risk-based prioritization methodology developed with the rest of Energy Systems.

- Goals and structure: institutional goals will be established, and roles and responsibilities will be clearly defined and will be used in performance planning and review. This will provide the means for higher-level goals to flow down to individual workers while providing the opportunity for staff to establish their personal goals and thereby gain "ownership" of these goals. The organizational structure that transfers ES&H assistance to the operating and research divisions will be improved. This includes strengthening the divisions' internal ES&H support and improving the ties between divisions and the central ES&H staff.

- Conduct of Operations: uniformity of management approach and formality of operations will be strengthened by the implementation of Conduct of Operations throughout ORNL. The rigor of Conduct of Operations will be based upon the risk involved; a graded approach will be used to recognize the wide variety of facilities at ORNL and their attendant risks. Comprehensive evaluations by trained line management are used to determine the relative risks at facilities and the needed upgrades to procedures, training, or equipment.

- Surveillance: effective and independent oversight of ES&H performance will be established, and adequate technical assistance will be provided. The oversight and technical assistance roles will be managed to avoid conflicts of interest. Audit management improvements will create a more effective system for coordinating the large number of internal and external assessments that occur.

Table 6.7. Total environmental, safety, and health (ES&H) cost summary[a]
($ in millions – BA)

	Fiscal year						
	1991	1992	1993	1994	1995	Beyond	Total
Tiger Team-Related Costs							
One-time costs	61.6	88.0	169.9	127.9	172.4	457.9	1077.7
Annual ongoing costs	0.7	7.8	12.1	13.8	14.0	>26.0	>74.4
Subtotal	**62.3**	**95.8**	**182.0**	**141.7**	**186.4**	**>483.9**	**>1152.1**
ES&H-Related Portion of Other Costs							
Overhead	35.7	37.3	39.0	40.7	42.6	*b*	>195.3
Operating legacy cost[c]	*b*	*b*	*b*	*b*	*b*	*b*	*b*
General plant project	2.5	4.8	15.0	*b*	*b*	*b*	>22.3
Multiprogram general-purpose facility	0.0	1.1	16.4	18.2	40.0	333.0	408.7
Line items	0.0	*b*	*b*	*b*	*b*	*b*	*b*
Waste management	10.8	28.5	27.3	31.5	91.5	*b*	>189.6
Subtotal	**>49.0**	**>71.7**	**>97.7**	**>90.4**	**>174.1**	**>333.0**	**>815.9**
Total ES&H cost	**>111.3**	**>167.5**	**>279.7**	**>232.1**	**>360.5**	**>816.9**	**>1968.0**

[a]Costs are based on Revision 4 of the ORNL Tiger Team Action Plan.
[b]To be determined.
[c]Dependent on DOE funding of ES&H field work proposals and line items.

- Measurement: performance goals will be established, and tracking and trending systems will be implemented. A set of performance indicators will provide periodic status reports on key aspects of ES&H and R&D performance. Corrective action management will be improved through the development and use of an Energy Systems tracking data base. This will be based on a computer mainframe and will be accessible to personnel across the site. Comprehensive reports and notification systems will provide better communication on the status of actions, leading to more effective management.

- Self-assessment: a continuous self-assessment process combined with periodic independent external review that meets all the criteria for an effective self-assessment program will be implemented. This program will include independent appraisals of the Laboratory for the ES&H disciplines, traditional QA audits and surveillances, and assessments by divisional line managers.

- Total Quality Management: a philosophy of continuous improvement and dedication to excellence will serve as the umbrella under which elements are defined and implemented. At ORNL it is planned to take advantage of the TQM principles in a research setting to address areas where the most impact can be made. To do this, it will be determined where these principles are in place and where they can be applied. This information will be communicated to all staff with a master list of potential activities. Training on TQM is proceeding and is being well accepted by the staff.

The most critical issue facing ES&H management is the need for direct funding for ES&H. Current funding is not adequate for ORNL to respond aggressively to the issues confronting it. Further funding through overhead threatens to make ORNL noncompetitive. Further discussion on this topic is provided in the "Scientific and Technical Programs" section, under "New Initiative: Direct Funding for ES&H Compliance Efforts."

From a regulatory standpoint, a major issue facing ORNL is the Tennessee-DOE oversight agreement. This agreement, negotiated between DOE and the state, will allow unlimited access on a day-to-day basis for up to 90 state regulatory inspectors. The resources required to escort these inspectors and to respond to their concerns will severely impact our limited staff. This may cause delays in other required actions unless additional resources are provided, as requested in the direct-funding initiative.

Environmental Restoration and Waste Management Activities

Waste Management (WM) activities and surplus facilities management aspects of environmental restoration (ER) are managed at ORNL by OWMRA, under the associate director for operations (Fig. 6.1). Site characterization and remediation aspects of environmental restoration for ORNL are managed by 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 waste have been radioisotope production; experimental reactors; hot cells and pilot plants (chemical separations of 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 (SWSAs) 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 (^{90}Sr, ^{137}Cs), tritium, and activation products (e.g., ^{60}Co) rather than by TRU (or uranium).

In 1985, ORNL created the Environmental Restoration and Facilities Upgrade Program to improve waste management and environmental restoration, enhance regulatory compliance capabilities, and provide comprehensive long-range planning. Energy Systems has recently established a central ER Division, a central WM Division, and a central Decontamination and Decommissioning Program with reservationwide management and oversight responsibilities. At ORNL, OWMRA 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 OWMRA 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 P&E Division) 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 both DOE Headquarters and DOE-OR, and Energy Systems.

The mission of the WM Section is to provide quality WM capability in compliance with applicable requirements. This mission is carried out through strategic planning; development of new or upgraded facilities; routine waste collection; and waste treatment, storage, and disposal (TSD). The WM component manages radioactive (low-level as well as transuranic), hazardous, mixed radioactive and hazardous, medical/infectious, and solid sanitary/industrial wastes. Waste forms include gaseous, liquid, sludge, and solid. The WM Section operates 34 facilities at the Laboratory.

The WM Section covers ongoing operation and upgrading of ORNL WM facilities needed to support programmatic missions of DOE. Additionally, it provides for management of wastes produced as a result of pioneering radiochemical operations and research that supported the early mission of Defense Programs (DP) and its DOE predecessors.

Funding for WM activities has increased steadily since FY 1985. Expense funding has grown from about $3.5 million in FY 1985 to about $29 million in FY 1990. Expected expense funding in FY 1991 is about $37 million, which is well below the requirements level. In addition, capital funding [line item (LI) and general plant projects (GPPs)] during the FY 1985 through FY 1990 period has been available at a level of about $15 million annually. These funding levels have provided the basis for continuing long-range strategic 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 liquid low-level waste (LLLW) include an aggressive waste minimization campaign that resulted in reduction of LLLW generation rate by about 60% during the period FY 1985 through FY 1990 and the solidification of about 47,500 gallons of LLLW during FY 1989. ORNL has also successfully adapted the tumulus approach for disposal of solid low-level waste and completed a demonstration of this technology. 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 (FFA) for active LLLW tank systems is being implemented as are waste minimization activities to support a comprehensive program to provide leadership, guidance, technical support, coordination, tracking, and reporting for reduction of all categories of wastes. WM GPPs for TSD upgrades are provided. LI projects include two for implementation of the active LLLW tank systems requirements of the FFA, and one each for construction of the TRU Waste Handling and Processing Plant, the Waste Characterization and Certification Facility, and the Process Waste Treatment Plant replacement project. Out year activities in WM include continued operation of waste treatment, storage, and disposal facilities with many major upgrades. Waste reduction will continue to be emphasized, and TRU waste will be treated and stored for eventual shipment to DOE's Waste Isolation Pilot Plant in Carlsbad, New Mexico. Additional reservationwide WM facilities will be added to promote efficiency and improved ES&H conditions. Tables 6.2 and 6.3

Table 6.2. Waste Management Cost Summary
($ in millions—BA)

	Fiscal year							
	1990	1991	1992	1993	1994	1995	1996	1997
EW30—Environmental Restoration and Waste Management—Defense								
OP[a]	17.0	27.1	31.6	37.8	39.1	35.5	41.5	43.8
CE[b]	0.8	1.6	3.1	2.0	2.0	2.0	1.5	1.5
GPP/LI[c]	3.3	1.9	7.9	4.9	6.1	6.1	6.1	4.6
Total	**21.1**	**30.6**	**42.6**	**44.7**	**47.2**	**43.6**	**49.1**	**49.9**
EX30—Environmental Restoration and Waste Management—Nondefense								
OP	12.0	9.8	15.1	17.9	18.6	20.7	24.5	26.9
CE	0.7	0.7	2.1	1.1	0.6	0.5	0.4	0.4
GPP/LI	9.0	8.9	7.8	10.1	14.5	12.9	8.0	13.0
Total	**21.7**	**19.4**	**25.0**	**29.1**	**33.7**	**34.1**	**32.9**	**40.3**
Summary (EW30+EX30)								
OP	29.0	36.9	46.7	55.7	57.7	56.2	66.0	70.7
CE	1.5	2.3	5.2	3.1	2.6	2.5	1.9	1.9
GPP/LI	12.3	10.8	15.8	15.0	20.6	19.0	14.1	17.6
Total	**42.8**	**50.0**	**67.7**	**73.8**	**80.9**	**77.7**	**82.0**	**90.2**

[a]Operating expense (OP) includes some Environmental Restoration funding for Waste Management and Isotopes shutdown through FY 1994.

[b]Capital equipment.

[c]General plant project/line item.

Table 6.3. Waste Management personnel
[full-time equivalents (FTEs)]

	Fiscal year							
	1990	1991	1992	1993	1994	1995	1996	1997
EW30—Environmental Restoration and Waste Management—Defense								
Technical	71.9	111.3	120.6	127.3	134.9	116.3	129.6	130.3
Other direct	18.0	27.8	30.1	31.8	33.7	29.1	32.4	32.6
Total	**89.9**	**139.1**	**150.7**	**159.1**	**168.6**	**145.4**	**162.0**	**162.9**
EX30—Environmental Restoration and Waste Management—Nondefense								
Technical	50.7	39.2	57.4	57.2	64.2	67.8	76.7	80.0
Other direct	12.7	9.8	14.3	14.4	16.1	16.9	19.2	20.0
Total	**63.4**	**49.0**	**71.7**	**71.6**	**80.3**	**84.7**	**95.9**	**100.0**
Summary (EW30+EX30)								
Technical	122.6	150.5	177.9	184.5	199.1	184.1	206.3	210.3
Other direct	30.7	37.6	44.5	46.2	49.8	46.0	51.6	52.6
Total	**153.3**	**188.1**	**222.4**	**230.7**	**248.9**	**230.1**	**257.9**	**262.9**

show funding and personnel by EM for WM activities.

ORNL's ER activities involve both inactive waste sites and inactive facilities. Waste sites constitute most of ORNL's environmental contamination. A wide variety of liquid and solid wastes, primarily radioactive or mixed wastes, has been disposed of on site. 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. 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. Efforts to characterize the ORNL areas and to provide a basis for determining appropriate remedial actions are in progress. These environmental restoration waste-site activities are administered directly by the Energy Systems ER Division.

The ORNL D&D program began in 1976. S&M has been conducted to ensure protection of employees and the public and containment of contaminants. ORNL has successfully decommissioned five facilities during the period from 1979 through 1990. 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. One project

is currently active at ORNL and involves the decontamination of processing cells at the Metal Recovery Facility.

The annual budget for S&M is approximately $3 million. The budget for decommissioning of surplus facilities is highly variable and is subject to annual reprioritization by DOE. There is no funding in FY 1991 for decommissioning of ORNL facilities. Some minor decontamination efforts will continue in FY 1991, however, utilizing funds carried over from FY 1990.

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, these facilities will be decontaminated and decommissioned 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 collectively manage all activities relating to surplus contaminated sites and facilities.

There are currently 101 inactive surplus facilities, including former SWSAs, 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 ORNL Remedial Action Section is responsible for S&M of all areas and D&D of the contaminated facilities.

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.

D&D projects are implemented according to priorities set at the national level by the DOE Headquarters D&D Program. Budget requests for decommissioning of prioritized facilities at ORNL are submitted annually and included in the DOE Environmental Restoration and Waste Management Five Year Plan. These priorities are then ranked with facilities from other DOE installations, and budgets are allocated accordingly. Projects are then implemented by the ORNL Remedial Action Program in accordance with these budget allocations. No ER funding is shown in Tables 6.1 or 6.2.

7. contributions to economic competitiveness

7. Contributions to Economic Competitiveness

Technology Transfer

Over 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 Martin Marietta Energy Systems, Inc., (Energy Systems) Office of Technology Transfer (OTT) has concentrated its attention primarily on executing license agreements, which now total 53. From these licenses, we have collected over $1.4 million in royalties from over $35 million in commercial product sales. Based on our royalty sharing program, we have distributed over $235,000 to our employees. We have also seen the number of industry guest researchers spending at least 2 weeks at the Oak Ridge National Laboratory (ORNL) rise from 344 in 1985 to 972 in 1990. 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 about $40 million in 1990, highlighted by the opening of manufacturing facilities of two technology clients: Hertel Cutting Technologies, Inc., and Coors Technical Ceramics Company.

The future looks even more promising. In FY 1991, we have added a new tool that will greatly increase the commercialization of new inventions made at the U.S. Department of Energy (DOE) laboratories through 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 agreements and CRADAs. In addition, we are targeting a threefold increase in active licensing agreements.

Introduction

On January 23, 1991, Admiral James D. Watkins issued SEN-30-91, "Setting the Course for Technology Transfer at the Department of Energy." In the notice, Admiral Watkins set forth the following:

> The DOE technology transfer mission is to help enhance U.S. competitiveness and national security, by expanding and accelerating the transfer of Federally-funded technologies and knowledge into commercial applications by U.S.-based industry.
>
> In support of this mission, DOE will:
>
> 1. Increase the level of U.S.-based industry participation in DOE's research and development at all stages of program development and execution.
>
> 2. Increase the level of DOE program and laboratory activity in transferring technology, consistent with other program missions and authorities.
>
> 3. Accelerate the process of transferring technology and knowledge to U.S.-based private industry and consumers and State and local governments.

Industrial Partnership Programs

To a growing extent, the exceptional scientific and technical developments that emanate from ORNL are being translated into new American-made products and jobs requiring new capital investments. The Laboratory's aggressive technology-transfer program is providing the catalyst for this evolution. This program recognizes the importance of face-to-face interactions between ORNL researchers and managers and their industrial counterparts. Although ORNL researchers are not in the business of new product development, they are encouraged to become more sensitive to the potential commercial outcome of mission-related work.

The gap between research and development (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 (created by the National Competitiveness Technology Transfer Act of 1989, P.L. 101-189) provide a means to bridge that gap. They provide industry with the opportunity to fully access the broad R&D capabilities at the DOE facilities in Oak Ridge. CRADAs provide an extremely significant means for sharing the capabilities, facilities, and technologies in Oak Ridge with U.S. industry, universities, and other R&D organizations for the purpose of improving our national competitiveness. A CRADA is, in effect, a joint R&D mechanism. It allows ORNL to enter into cost-sharing arrangements that allow negotiated terms for the handling of background and resulting intellectual property, including the protection of technical data for up to 5 years. Such arrangements are structured to leverage R&D funds both for DOE and the CRADA partner, which is particularly important in times of scarce R&D resources.

CRADAs provide the means to work together with industry, a way to rub elbows at the scientific bench, which is the most effective way to transfer technology. It is a person-to-person transfer of the technology and the expertise. The Energy Systems licensing program, which has 54 licenses to-date, has successfully demonstrated that technology from a national laboratory can be effectively commercialized. Most licensees, however, would like to find a way to continue the relationship with Energy Systems by tapping the expertise here, using our excellent facilities, and further developing the technology. We fully expect licenses to lead to CRADAs, but that also CRADAs will result in new licenses. The two aspects of technology transfer will be highly complementary and integrated.

To promote this important new authority, we commissioned a videotape describing CRADA opportunities in Oak Ridge. A multiple-wave mailing is now being conducted beginning with the new-business-development executives from the Fortune 500 manufacturing firms. Additional mailings are planned for the membership of the Industrial Research Institute as well as ORNL R&D subcontractors and regional manufacturing firms. At the end of FY 1991, ORNL had executed 15 CRADAs. We anticipate that ORNL will enter into an average of 25 to 30 CRADAs each year over the next 5 years.

CRADA Emphasis Areas

CRADAs that have been executed illustrate the variety of partnership arrangements that will be emphasized in the future as well as the wide variety of technologies and capabilities available to prospective partners.

User Facilities One of the first ORNL CRADAs to be executed (with the Cellulose Industry Standards Enforcement Program) is utilizing the Roof Research Center (RRC), a designated ORNL "user facility," to evaluate the thermal performance of cellulose insulation in a conventional attic. As with all user facilities, the RRC is equipped to conduct R&D using unique facilities and equipment not otherwise available to industry. CRADA discussions are under way on similar projects with numerous other firms and consortia to perform research in such other user facilities as the High Temperature Materials Laboratory (HTML) and the Surface Modification and Characterization Facility.

Individual Firms CRADAs with individual firms can create new opportunities to advance specific DOE programmatic objectives while, at the

same time, assisting U.S.-based manufacturers in addressing important developmental objectives. CRADAs, for example, may assist both industry and the DOE in the resolution of serious environmental problems. One large-scale project of this nature will bring together multidisciplinary research teams from ORNL and General Electric Company. The goal is creation of a cost-effective, comprehensive biotechnology-based system to solve problems related to polychlorinated biphenyls at DOE facilities and in private industry. Success in this multiyear endeavor is expected to have widespread consequences.

Multiple Firms Advanced ceramic-materials applications in key industrial sectors are dependent upon the development of critical technologies in manufacturability. Technologies enabling the profitable machining of advanced ceramics have not been effectively addressed at the federal level, and they represent too high a risk for the private sector to tackle alone. The automotive leaders, for example, have all but abandoned R&D endeavors to machine ceramic engine parts because cost projections remain unreasonable and ceramic expertise remains concentrated in the federal laboratories.

A program will be organized and structured to respond to industrial needs that are consistent with identified DOE requirements. Initial activities will include (1) a comprehensive needs analysis, jointly funded by Defense Programs (DP), Conservation and Renewable Energy (CE), and private participants, and accomplished by Oak Ridge Y-12 Site Development Division, ORNL Metals and Ceramics Division, and National Center for Manufacturing Sciences (NCMS) members; (2) development of characteristic strength data of selected ceramic materials through a CRADA with U.S.-based ceramics firms; and (3) preliminary machining studies proposed for CRADAs with aerospace and automotive companies. Requirements documentation will be created from these initial activities, providing the definition of an optimum program responding to both DOE and private-sector needs.

Initial activities are anticipated to result in the development of a Ceramics Manufacturability Program involving the HTML, a consortium of key industrial firms, and a manufacturing-technology center operation of the Y-12 Site. The superior nondestructive evaluation capabilities of the HTML will be augmented by appropriate manufacturing equipment and systems resident in the Y-12 Site and coordinated with an array of test beds at major companies. This program will be a natural evolution of both the materials research of the HTML and the machining development efforts of the Y-12 Site and the ultimate operation will be an integration of the capabilities currently existing at both sites. This preliminary view is the result of early assessments provided through meetings with the named private companies.

This approach of integrating the capabilities of DP's Y-12 Site operation and CE's HTML is based upon specific needs that can be satisfied only through such a combination. The combined expertise in materials provided by the HTML organization and the most complex machining operations provided by the Y-12 Site will be necessary to lead the world into the era of manufacturable ceramics.

University Partners CRADAs provide an opportunity for ORNL to combine expertise with university partners to address important industrial problems. For example, ORNL and University of Tennessee (UT) researchers are working together with technical specialists at Dow Chemical Company in a project that could have major economic ramifications. The objective is to reduce power consumption in the production of magnesium metal by monitoring and adjusting the contents of molten baths at Dow's massive production facility in Texas. Commercial-scale deployment of the technology, in an energy-intensive process, could lead to significant cost savings for numerous U.S. companies, including those in the aluminum industry.

"Spin-Off" Technologies

The DOE Office of Energy Research (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 an ER laboratory, with preference for technologies originally developed using ER funds.
- The technology should be a spin-off or "orphan" technology (i.e., 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 1991 with a total budget of $400,000. We anticipate that up to eight projects will be funded in FY 1992 with a total budget of $800,000. Based on DOE-ER projections, this program could grow to $3,000,000 by FY 1996.

Environmental Technology Integration

Energy Systems has accepted the task to support the DOE's Environmental Management Technology Integration Branch. This mission is to facilitate timely and effective applications of generic, precompetitive technologies to meet DOE's environmental-restoration and waste-management needs through collaborative partnerships with U.S. industry, the DOE laboratories, other federal agencies, universities, and appropriate international participants and to provide for technology transfer "in" as well as "out" to accomplish technology integration.

DOE has established Integrated Demonstration sites at facilities throughout the United States to test and monitor those technologies that are deemed ready for commercialization. This program is open to all parties on a cost-share basis and will demonstrate actual use applications. An Integrated Programs project has been started to enhance cooperation between DOE, industry, universities, and other government agencies having similar environmental problems. Movement of technology among these institutions can lower costs, save time, and avoid duplication of effort for all participants.

An International Technology Integration Program has been started to enable transfer "in" and "out" of needed environmental technologies between DOE and foreign governments, universities, and industries. This program will also provide a means for U.S. industry and universities to interact with their foreign counterparts for commercial business activities.

Developing human resources by reaching out to industry is essential in environmental-restoration and waste-management activities. It is an indisputable fact that environmental concerns are more pressing issues today than in any other time in human history. Change of culture and organizing a new philosophy in the environmental issues around the country will remain as a basic behavior of future generations and can only be established through a systematic approach. A joint program of ORNL and The University of Tennessee, Knoxville (UTK) has been initiated to provide education and research on waste management. The objective of the program is to train a human resource base to provide skills and capabilities for the DOE Office of Environmental Restoration and Waste Management (DOE-EM) and industry personnel to perform environmental restoration and waste management. The program will provide the opportunity for formal education and research for the commercial sector while integrating their efforts with UTK and ORNL in waste management. Initially, the program's principal resources will be the staffs and facilities of ORNL and UTK. The two institutions have a long history of successful collaboration.

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 work on the part of the private firm in order 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. Over the past 3 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.

During 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 can not be sold back to the government for profit).

Licensing Program

From the beginning, OTT (formerly the Office of Technology Applications) has concentrated its efforts on those areas of technology development for which Oak Ridge has become known for excellence. Over the last 3 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 over 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.

In order 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 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.

Gamma-Metrics is a privately held firm in San Diego, California, specializing in devices that detect explosives in baggage and sulfur content in coal using neutron-bombardment techniques. The firm was founded in 1980 as a spin-off of Sorrento which, in turn, was a spin-off of General Atomics. Energy Systems has recently exclusively licensed the surface-enhanced Raman spectroscopy (SERS) chemical analysis technology to Gamma-Metrics for use in hazardous waste analyses. Gamma-Metrics has committed to an aggressive development plan to bring the product onto the market within the next 12 months. The program will require a significant level of interaction between scientists from both organizations to successfully complete. Gamma-Metrics has committed to working on a funds-in CRADA with ORNL to support the work of members of the Health and Safety Research Division.

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;
- reward 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 the 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 3 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 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 that will begin to be implemented in FY 1992.

- Audience
  - Review current mailing list to cull out entries unlikely to be oriented toward technology acquisition.
  - Begin to collect information on information inquiries (by means of a trade press "bingo card") that we can catalog and sort areas of interest for future, related mailings.
  - Targeted mailings of selected bulletins to firms with 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 a brief (two- to three-sentence) abstract of the bulletins.
  - An additional approach being pioneered by the National Institutes of Health is the idea of an electronic bulletin board that can be accessed by interested firms.

- Cover
  - Produce an OTT logo that can be used to distinguish our future mailings; one suggestion was to run a contest for a logo design within art classes of area schools, with a prize paid for out of royalties.
  - 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 alternative 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 Technology Evaluation

Committee meeting, 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/ pictures for preparation of technology viewgraphs.

Business Management and Budget

The budget for OTT in FY 1990 was $1.4 million; the number of full-time equivalents (FTEs) supported was 15.8 (Table 7.1).

Productivity Indicators

Royalty income and the number of new licenses is 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 1990 will exceed a cumulative total of $30 million.

Table 7.1. Estimated staffing and expenditures for the Office of Technology Transfer[a]

	Fiscal year						
	1991	1992	1993	1994	1995	1996	1997
Funding ($ in millions—BA)							
ORTA activity[b]	1.72	2.15	3.54	3.72	3.91	4.10	4.31
Patent/licensing—activity	0.58	0.72	1.19	1.25	1.31	1.38	1.45
CRADA[c] funding—federal	3.90	12.40	20.60	21.63	22.71	23.85	25.04
CRADA funding—private industry	3.65	12.10	20.15	21.16	22.22	23.33	24.49
Total	**9.85**	**27.37**	**45.48**	**47.76**	**50.15**	**52.65**	**55.29**
Professional Staffing [full-time equivalents (FTEs)]							
ORTA activity	11.60	15.25	17.08	17.93	18.83	19.77	20.76
Patent/licensing	5.00	6.25	6.88	7.22	7.59	7.96	8.36
CRADA activity	3.00	3.00	3.00	3.15	3.31	3.47	3.65

[a]Funding for the Energy Systems Office of Technology Transfer includes ORNL, the Oak Ridge Y-12 Site, and the Oak Ridge K-25 Site.

[b]Office of Research and Technology Applications.

[c]Cooperative research and development agreement.

7.2. Office of Technology Transfer licenses executed (FY 1990)

Licensee	Technology
Canberra	Integrated alpha spectroscopy software
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

Table 7.3. Licensing income and use

	Fiscal year				
	1990	1991[a]	1992[a]	1993[a]	1994[a]
Licenses					
Number of new licenses	13	14	25	25	25
License income ($ in thousands))	500.00	597.00	1491.00	2485.00	3200.00
Use of income ($ in thousands)					
Invention and ORTA[b] administration	0.00	0.00	0.00	0.00	0.00
Scientific or applied R&D	355.00	348.65	1054.25	1790.91	2254.51
Awards and inventor share	125.00	149.25	372.75	621.25	800.00
Education/training	20.00	77.00	24.00	25.08	26.21
Other (federal income taxes)	0.00	22.10	40.00	47.76	119.28

[a]Projected.
[b]Office of Research and Technology Applications.

Table 7.4. Technology transfer results

	Fiscal year				
	1990	1991[a]	1992[a]	1993[a]	1994[a]
Patent application	21	30	56	39	40
Patents granted	23	30	54	37	38
Cumulative product sales[b]	30.4	48.1	57.7	75.0	101.3

[a]Projected.
[b]Dollars in millions.

Science Education and External Relations

Overview of ORNL's University and Educational Programs

The DOE's mandate to its multiprogram national laboratories to consider education as a primary mission is reflected in the new programmatic designation of ORNL and several other laboratories as "Science Education Centers." This role includes responsibility for the development and conduct of innovative programs that address needs in mathematics, science, and engineering education from the early elementary grade levels all the way through the laboratories' 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 research and development goals.

Since September 1989, when President Bush convened his "Education Summit" in Charlottesville, Virginia, the growing consensus on national education goals has placed strong emphasis in particular on the urgent need for strengthening mathematics and science education. The DOE-sponsored Math/Science Education Action Conference, convened in October 1989 in Berkeley, California, focused directly on this enlarging mission. Its working groups generated a series of recommendations and goals to be achieved by the year 2000 in five areas—students, teachers, underrepresented groups, public literacy, and competitive work force—together with an overall strategy to maximize the contribution and impact of the often-unique resources represented by DOE's laboratories and facilities. The February 1991 report, *By the Year 2000—First In The World*, by the Federal Coordinating Council on Science, Engineering, and Technology Committee on Education and Human Resources, a group chaired by Secretary of Energy James D. Watkins, further defines and develops the federal role in mathematics, science, and technology education at the precollege through graduate levels and elaborates that strategy on an agency-by-agency basis.

Over this same time frame, two visits to East Tennessee by Secretary Watkins—the second in February 1990 to accompany President George Bush—gave added momentum to ORNL's already substantial and growing commitment to precollege math and science activities for both students and teachers. In partnership with UT, ORNL was designated to expand its regional role as a science education center. New initiatives were announced to strengthen both pre-service and in-service professional-development opportunities open to teachers and teacher-candidates and to expand the teaching pool through an innovative program of alternative secondary-level certification for technical professionals who wish to pursue second careers in this field. Secretary Watkins also gave his strong endorsement to "volunteerism" in support of math/science education by DOE and contractor staff members and to expanded partnerships with area schools. The latter is evidenced by ORNL participation with Oak Ridge Associated Universities (ORAU) in the DOE-sponsored project, Science/Math Action for Revitalized Teaching (SMART), a partnership with the Chattanooga City, Harriman City, and Roane County School Systems in East Tennessee, and by three new ORNL school "adoptions" over the past year.

Other key new precollege thrusts include the ORNL-administered National Teacher Enhancement Project sponsored by the National Science Foundation (Fig. 7.1). This 3-year, $1.8 million program joins ORNL with four other DOE laboratories—Argonne, Fermi, Lawrence Livermore, and Pacific Northwest—to provide three-week summer workshops and academic-year followup activities for teachers of Kindergarten through eighth grade. During its first year, beginning in the summer of 1990, this program had 218 teacher participants nationally. A record 42 eight-week summer teacher research

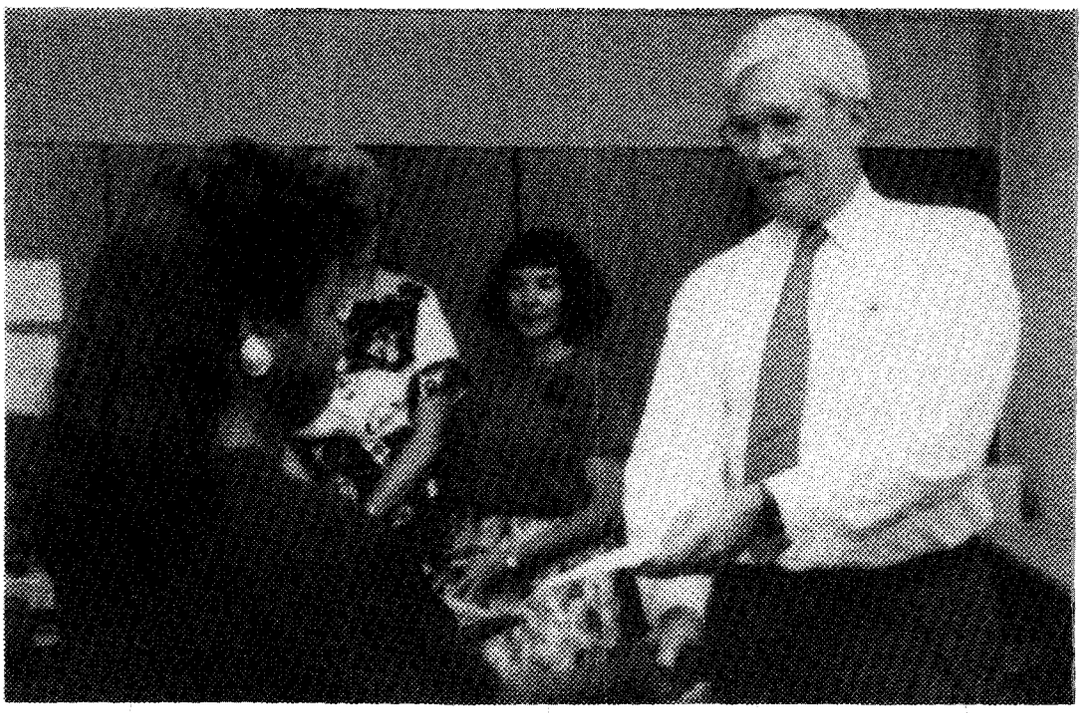


Fig. 7.1. Graduation ceremony for the National Teacher Enhancement Project Workshop in Oak Ridge.

appointments were made at ORNL through the DOE Teacher Research Associates (TRAC) Program; local initiatives during the summer of 1990 and the summer of 1991 increased to 55. The Laboratory also conducted the first two sessions of an 8-week Saturday Academy of Computing and Mathematics during the 1990–91 school term, with 75 student/teacher participants from 12 area high schools. A new honors-study program modeled after the DOE High School Science Honors Workshop in Environmental Sciences was piloted at ORNL under DOE's new memorandum of understanding on cooperative science-education activities with the Appalachian Regional Commission.

With program growth has come a need for increased focus and direction in planning and executing ORNL's educational efforts. A formal Long-Range Plan for the Science Education Center was adopted and published in September 1990. The plan incorporates both near- and longer-term actions through the Office of Science Education and External Relations at ORNL 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. The goals set forth are to be accomplished by extending and strengthening key linkages to educators and educational institutions at all levels and by addressing more systematically many identified opportunities for increasing the numbers, quality, and demographic diversity of trained scientists and engineers. Key thrusts of the plan are designed to

- strengthen the educational pipeline at its roots, qualitatively and quantitatively, through

innovative 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 as well as students, with special attention to teacher recruitment, preparations, 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 provides a framework and operating structure for addressing 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—and to have such creative experiences as a part of their earliest encounters with science. Undergraduate programs influence 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 programs, which make further use on the Laboratory's unique facilities and staff resources, help prepare emerging scientists and engineers for their role in national energy-related missions by providing a close association with ongoing energy research and development in a national laboratory setting. Faculty participation in cooperative research, employing the Laboratory's unique facilities and other technical resources, facilitates the two-way flow of technical information and helps to establish a strong professional connection between those in schools and colleges who are the primary producers of scientific and technical personnel and the practicing communities that will be the source of their future employment. (Fig. 7.2)

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 from 300 to 400 elementary and secondary teachers each year, some 125 students selected for special on-site honors-study activities on both a national and regional basis, and another nearly 20,000 student-teacher participants in hands-on "learning through research" experiences offered year-round through ORNL's core precollege program, the Ecological and Physical Sciences Study Center, which provides 40 different study units for visiting class-size groups and school outreach programs. Last year, ORNL conducted its first residential 10-week

Fig. 7.2 Summer Teacher Research Associate Participant in the ORNL Environmental Sciences Division.

summer research-participation program for students at the secondary level. This joint effort involved seven outstanding junior and senior students and two teachers from Puerto Rico.

A continuing strong emphasis in this comprehensive approach to strengthening the math/science educational pipeline has been ORNL's interactions with historically black colleges and universities and with other minority educational institutions. The Laboratory is a partner with two other national laboratories (Los Alamos and Sandia) in the historic DOE Science and Technology Alliance that in 1988 linked these facilities with three minority educational institutions—the Ana G. Méndez Foundation in Puerto Rico, New Mexico Highlands University, and North Carolina A&T State University. The DOE-sponsored Waste Management Consortium of 19 minority colleges and universities represents another key link, as is ORNL's participation in the National Consortium for Graduate Degrees for Minorities in Engineering, Inc. Currently ORNL administers 14 R&D subcontracts representing commitments of $2 million annually with minority institutions. The past year has seen the development of four new customized internship programs for students from minority institutions; these internships provide resident assignments in ORNL divisions at both the undergraduate and graduate levels.

DOE's University Laboratory Cooperative Program (ULCP), administered by the Office of Energy Research (OER), 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 provided through other sources, such as colleges and universities, fellowships, and grants.

ORNL plays an important role in the education and training of university students through myriad programs designed to provide research experience. 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;
- donating and loaning personnel and equipment resources;
- 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 very directly in the mission support gained especially from university-level participation programs. Manpower 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 at the same time making a vital educational and training contribution. Over 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 ORAU.

Many university personnel receive training or perform experiments on ORNL's state-of-the-art resources while they are under research-participation appointments. DOE supports a variety of university programs at ORNL, both through ULCP and programmatic funds.

Seventy-five co-op students were employed by ORNL in FY 1991; another 350 undergraduates and graduate students, 62 postgraduates, and 46 faculty members received research-participation appointments through the Office of University and Educational Programs. These numbers do not include the 50 college and university personnel who received travel contracts for short-term research visits.

Programs are available through ORAU that help support travel costs for university faculty and graduate students under research travel contracts. Additional programs support travel costs for Minority Educational Institution (MEI) researchers, such as Minority Institution Research Travel and Very Important Small Institution Travel Support. 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 a close relationship with several university consortia. For example, ORNL's long-standing collaboration with ORAU on educational programs has been strengthened through the implementation of several new joint programs as well as joint university outreach activities. In FY 1986 ORNL began discussions with the Southeastern Universities Research Association (SURA), which is another consortium of major universities in the Southeast. In FY 1989 ORNL became a partner along with ORAU and SURA in a new initiative to establish at ORNL a center for advanced study in materials science. This collaboration will provide a mechanism for faculty and students from SURA schools to work together 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. Papers will be issued through ORNL for the participants to receive their degrees. ORNL also continues a strong "science semester" program with the Great Lakes Colleges Association/Associated Colleges of the Midwest (GLCA/ACM), now in its third decade. And the DOE-sponsored Oak Ridge Science/Engineering Research Semester provides about 60 appointments of students on a national basis.

Research and Development Subcontracts

ORNL awards some 100 R&D subcontracts, valued at nearly $20 million, to more than 35 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 35% of ORNL's subcontract obligations are with UTK (including the cost for the joint appointments under the Distinguished Scientist Program and other activities under the state of Tennessee-supported Science Alliance, a UTK/ORNL Center of Excellence).

Research Collaborations

Many long-standing, close collaborations exist between ORNL and individual universities that 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 that are 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 a number of industrial partners. This program is designed to take full advantage of existing resources at all participating institutions. ORNL participates in the research, coordinates the overall effort, and conducts coordinated experiments and integrated equipment tests to demonstrate the overall progress of the team.

In 1988, ORNL established the Center for Global Environmental Studies to expand activities under the DOE-sponsored Carbon Dioxide Information Analysis and Research Program to include other trace gases important in the greenhouse effect, ozone depletion causes and effects, and the role of deforestation and reforestation in the climate issue. The center draws heavily on contributions from universities, other DOE laboratories, and other research institutions.

ORNL also participates in the DOE Excess Research Laboratory Equipment program that allows 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 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, such as Knoxville College, Tennessee Technological University, Pellissippi State Technical Community College, and Roane State Community College at the Oak Ridge campus.

ORNL staff also teach short courses as part of ORAU's 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 10 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 1990, over 300 university researchers performed experiments for over 5000 user days in ORNL's DOE user facilities. The largest percentage of the university-based users (31%) perform research at the Holifield Heavy Ion Research Facility. Other facilities heavily used by university researchers include 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 new 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

Much of ORNL's interest in precollege programs is in response to the federal government's renewed interest in science and mathematics education. 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 university in terms of poor precollege preparation and declining enrollment, especially of U.S. citizens and minorities.

For the fourth year, 60 U.S. and foreign high school students were hosted by ORNL in one of the DOE National High School Honors Workshops, with the focus on environmental research. Students work under the guidance of ORNL research staff members on small-group projects that examine effects of contaminants on the environment. The Special Honors Study Program implemented at ORNL in FY 1986 allows exceptional high school students to receive one-on-one instruction. Eight FY 1991 participants brought the total to 38 since the inception of this program (Fig. 7.3).

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 1991 program was expanded to 29 students who held 10-week summer appointments, including 11 Hispanic students from Puerto Rico. Participants are involved not only in research but also weekly career orientation activities and others that expand knowledge of frontier science (Fig. 7.4).

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 (ESC) of the Oak Ridge National Environmental Research Park. Developed by a team of educators, ESC began in 1983 with four study units, functioning during the spring and winter. The Study Center now includes 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 the academic level of elementary, junior high, or senior high school students. The Study Center now operates year-round, including Summer Science Saturdays for adult community members and children. During FY 1991 nearly 20,000 students participated, with a continuing

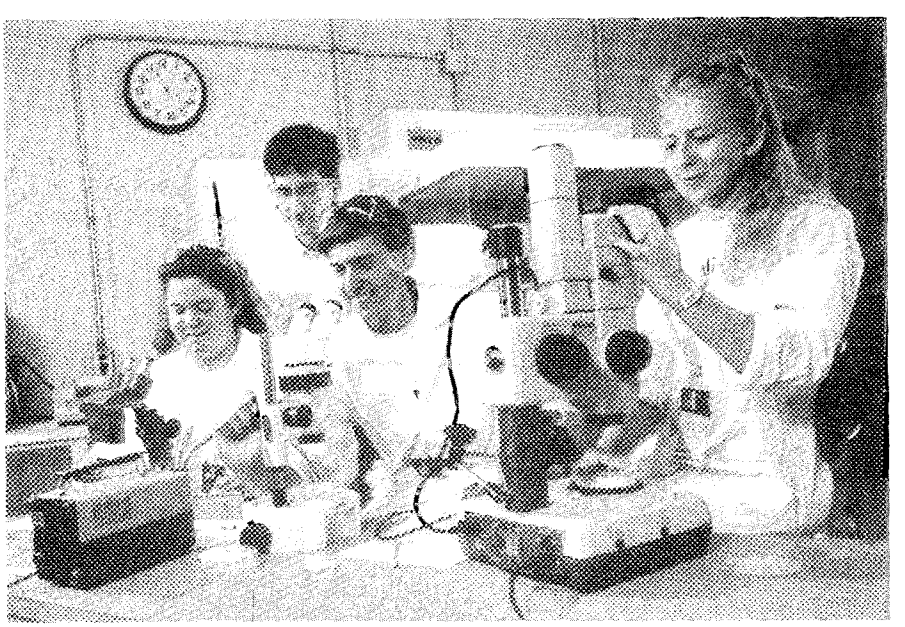


Fig. 7.3. DOE High School Science Student Honors Research Program participants

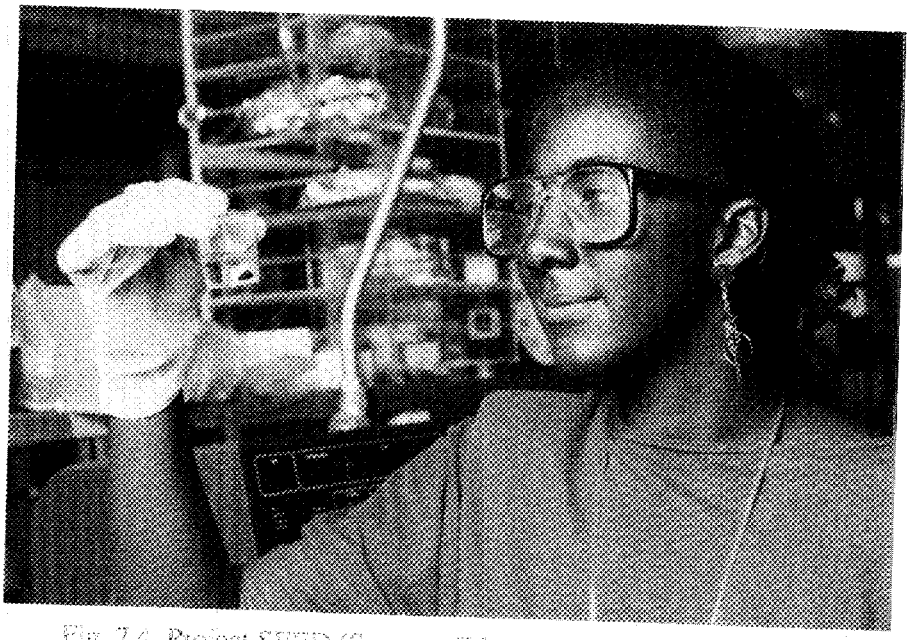


Fig. 7.4. Project SEED (Summer Educational Experience for the Disadvantaged) high school student from Puerto Rico.

special emphasis on students with physical and/or sensory disabilities (Fig. 7.5).

ORNL's first school partnership activity, PALS (Partners at the Laboratory in Science), began with the Oak Ridge schools in 1988. Since then the Laboratory has formally "adopted" two downtown Knoxville schools—Eastport Elementary and Vine Middle—that serve predominantly minority

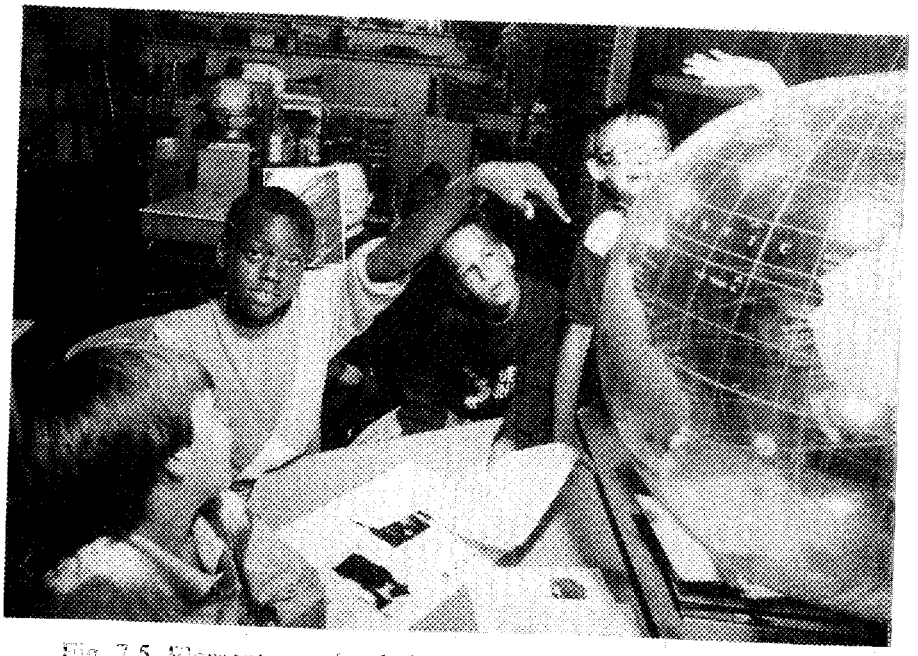


Fig. 7.5. Elementary school class project for National Space Week.

populations, Roane County High School in a neighboring largely rural area, and the Tennessee School for the Deaf. And the DOE-sponsored Project SMART extends this program to three other East Tennessee systems—Chattanooga City, Harriman City, and Roane County. The Laboratory's knowledge base and the unique skills of its staff are made available to area schools by means of these partnerships. Surplus equipment is also loaned to these schools. Access to this expertise and equipment enhances the education of the students and enables the teachers to develop professionally.

Undergraduate Programs

A prime emphasis in ORNL educational efforts lies with programs geared to mainly upperclass college and university students who major in science, mathematics, computer science, or engineering. The primary goal is to encourage these students to pursue graduate studies and careers in these disciplines.

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. DOE's Science and Engineering Research Semester 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. The Science and Engineering Research Semester attracts students from colleges and universities across the United States, with nearly 60 participants each year at ORNL. Other programs providing extended term appointments for undergraduates include the ORAU 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 in 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 approximately 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 Program, another relatively new program, provides summer research opportunities for rising seniors from the U.S. military academies.

Graduate Programs

Prethesis graduate master's degree and Ph.D. candidates, others performing thesis or dissertation research, and postdoctoral applicants are appointed to ORNL through various graduate education programs. Their 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 home 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 the Laboratory graduate participation (thesis research) participants must be accepted by ORNL's Graduate Fellowship Selection Panel or through national panels established by DOE's Office of Health and Environmental Research (OHER) and Office of Fusion Energy. During FY 1991 two new programs were introduced by OHER 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 62 postdoctoral fellows and 12 doctoral candidates performing thesis research were in residence during FY 1991. In addition, ORNL makes several postdoctoral appointments annually through its own Eugene P. Wigner postdoctoral fellowships administered by the Human Resources Division.

Graduate degree candidates, performing research for thesis or dissertation, work under the

supervision of a graduate committee composed of representatives from their school and ORNL. Postdoctoral appointments provide valuable research contributions to ORNL staff and divisions which directly support programmatic needs at the Laboratory.

Students who have not yet completed the required course work can participate in the ORAU Professional Internship Program for graduate students and the ORAU 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.

Science Alliance

The Science Alliance, funded by the state of Tennessee, ORNL, and DOE as part of the Comprehensive Education Reform Act, is another example of collaboration between ORNL and the University of Tennessee. The Science Alliance encourages joint research between ORNL and UTK, thus fostering a unique environment for research training. The most visible activity under this umbrella 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 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 Science Alliance also sponsors a summer research program at ORNL for undergraduates and the development of 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, yet 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 40 graduate students and postdoctoral appointees.

Similarly, the Graduate Program in Ecology, located within the Environmental Sciences Division (ESD), 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.

Minority Educational Institutions

ORNL continued to expand the number and dollar value of its program interactions with Minority Educational Institutions (MEIs) during FY 1991.

The main thrust continues to be on generating collaborative opportunities through internal and external interactions. Internally the program emphasizes communication of the 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.

As part of the historic memorandum of understanding and intent, forming support for the DOE Office of Energy Research Science and Technology Alliance, ORNL continued collaborations with the alliance educational

institutions, which include North Carolina A&T State University (NCA&TSU), New Mexico Highlands University, and the Ana G. Méndez Educational Foundation. For the third year ORNL provided funding to NCA&TSU in the amount of $372 thousand to support program administration, student and faculty development, curricula development, and special precollege programs to help encourage science and engineering students.

FY 1991 also saw extensive interaction between ORNL and Alliance faculty and students from the Méndez Foundation in Puerto Rico. For the third year, ORNL provided support to New Mexico Highlands University in the establishment of a library to support their efforts toward accreditation by the Accreditation Board of Engineering Technology 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 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 a minority institution 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.

During the summer of 1991, eleven outstanding Puerto Rican high school students and two supervising teachers selected by the Méndez Educational Foundation were brought to Oak Ridge for 10-week research appointments. Each carried out his or her own independent research project and prepared a summary research report on the experience; the report was reviewed and approved by the staff mentor. The students also took part in a weekly seminar with 10 other students appointed from schools in the East Tennessee area. At these sessions, students shared the progress of their individual projects and heard informal talks on various ORNL research programs, including fusion energy, genetic engineering, neutron activation analysis, and robotics. These very high-ability students and teachers selected by the Méndez foundation for this experience proved not only to be 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 memoranda of understanding with three other MEIs: Southern University, Clark Atlanta University, and Tuskegee University.

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 math 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 are especially important in expanding science and technology capabilities through sponsoring faculty research participation and visits at ORNL and through ORNL staff visits and lectures on campus. Collaborative research programs with university personnel continue to be a highly cost-effective method to receive quality assistance in fulfilling the Laboratory's important national R&D missions (Table 7.5).

Table 7.5. Programs at Oak Ridge National Laboratory for precollege and university participants (FY 1991)
(Number of participants)

Precollege Students			
Special Honors Study	8	Summer Educational Experience for the Disadvantaged (Project SEED)	18
DOE Honors Workshop	59	Hispanic SEED (Science and Technology Alliance)	11
Ecological and Physical Sciences Study Center	19,700	Appalachian Regional Commission	31
Clinch River Environmental Studies Organization	30		
Summer Science Experience	50	**Total**	**20,010**
Science and Mathematics Action for Revitalized Teachers Project (SMART) Math Quest	68		
Wesleyan College Spectacles	35		
Precollege Teachers			
National Science Foundation Workshop	45	Science and Technology Alliance	2
DOE Honors	6	University of Tennessee Teacher Academy	73
Appalachian Regional Commission	10	New Explorers Workshop	50
DOE Teacher Research Associates	55		
DOE Lyndhurst Fellows	10	**Total**	**355**
Project SMART Workshops	74		
Hands-On Science Workshop	30		
Undergraduate			
Great Lakes Colleges Association/Associated Colleges of the Midwest Science Semester	25	HBCU Cooperative Education	20
Special Summer Program (SERS)	22	Science and Technology Alliance	
Summer Research Internship (HBCU)	49	Science and Engineering Research Semester	59
Professional Internship Program	25	Student Research Participation	31
Technology Internship Program	22	Hazardous Waste Interns	3
Historically Black Colleges and Universities (HBCU) Nuclear Energy Training Program	17	Customized Internships	10
Service Academies Research Associates	2	**Total**	**287**
Graduate			
Services Academy Research Associates	2	Law Internship Program	5
Professional Internship Program	20	Graduate Education for Minorities	2
Laboratory Graduate Participation	12		
Graduate Student Research Participation	13	**Total**	**67**
Nuclear Engineering Research Participation Program	13		
Postgraduate			
ORNL Postgraduate Research Appointments	24		
Hollaender Postdoctoral Program	6	**Total**	**62**
Postgraduate Research Training Program	29		
Fusion Energy Postdoctoral Program	3		
Faculty			
Faculty Research Participation	31	University of Puerto Rico	1
Minority Institution Research Travel	5	Great Lakes Colleges	3
Research Travel Contracts	50		
HBCU Faculty	11	**Total**	**101**

Guest Research and User Facility Programs

During 1989 the Office of Guest and User Interactions (OGUI) was established within the ORNL Central Management Organization to enhance the level of service and to improve the environment for Laboratory guests, to encourage cooperative R&D, and to facilitate access to user facilities by external scientists and organizations. The OGUI includes the Foreign National/Guest Services Offices and a contracts group. A member of the Office of General Counsel provides legal assistance as needed to support the OGUI Program. The OGUI works with the DOE Oak Ridge Field Office, ORNL staff, and external researchers to develop and to implement streamlined procedures and services related to the performance of research at ORNL by guest scientists and engineers.

User Facilities

ORNL has 10 highly sophisticated user facilities designed to serve both the technical community and DOE missions by making these highly sophisticated facilities available for use by outside organizations. Since the user program was started approximately 10 years ago, these facilities have become an increasingly important factor in attracting scientists from industries and universities to the Laboratory. In 1990, 421 academic and industrial guest researchers, 411 government laboratory researchers, and 64 foreign scientists conducted experiments at ORNL user facilities (Table 7.6 and Figs. 7.6 and 7.7).

Traditionally, more than one-half of these visiting scientists represent universities. However in 1990, 30% of the total users were university scientists. Since the establishment of the HTML user facility in 1987, the number of industrial users has been growing. In the ORNL user program in 1990, 84 industrial researchers representing 46 companies participated. In June 1990 the High Flux Isotope Reactor (HFIR) was restarted and began to operate at full power for the first time in more than 3 years. Two HFIR user facilities, the Small-Angle Scattering Research Center and the Neutron Scattering Facility, which were directly affected by the 1986 shutdown, are again attracting users (Fig. 7.8).

Guest Research

Users constitute only a part of the large number of guest researchers who work with Laboratory scientific staff for periods ranging from 2 weeks to 2 years. These interactions broaden the Laboratory's base of expertise and support its mission of scientific cooperation and technology transfer. In 1990 the Laboratory population was augmented by 2915 guest research assignments (Tables 7.7 and 7.8). Of this number, approximately 1000 were foreign nationals representing more than 50 countries. In the last 5 years the number of guest assignments at the Laboratory has more than doubled.

The Future

With more emphasis on cooperative research, the guest research population at the Laboratory is expected to continue to grow. New user facilities will expand the user program and will attract additional participants. Other programs such as the Advanced Neutron Source, the ORNL Detector Center, and the Optics Manufacturing Operations Development Integration Laboratory are expected to attract increasing numbers of guest scientists to ORNL. The OGUI will continue to enhance services that make the Laboratory more accessible and promote a friendly environment for guests.

Table 7.6. Experimenters at designated user research facilities in FY 1990

	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)	45	6	31.9	104	24	59.3	0	0	0	30	18	8.8	179	48	1,761
National Environmental Research Park (NERP)[c]	82	6	40.2	60	25	42.1	14	6	17.5	3	1	0.2	159[c]	38[c]	4,534[c]
High Temperature Materials Laboratory (HTML)	93	3	53.5	40	19	18.3	50	28	28.2	0	0		183	50	3,321
Surface Modification and Characterization Laboratory (SMAC-RC)	43	7	65.9	29	17	12.4	7	5	2.0	7	4	19.7	86	33	1,548
Shared Research Equipment (SHaRE)	31	1	80.7	10	9	13.3	1	1	0.1	5	5	5.9	47	16	841
National Center for Small-Angle Scattering Research (NCSASR)	13	4	42.3	21	11	40.5	5	2	6.0	3	2	11.2	42	19	377
EN Tandem Van de Graaff	43	1	33.4	67	8	66.6	0	0		0	0		110	9	1,314
Oak Ridge Electron Linear Accelerator (ORELA)	39	2	90.5	1	1	4.2	0	0		3	2	5.3	43	5	1,509
Bioprocessing Research Facility	6	1	50.0	3	3	39.4	3	1	10.6	0	0		12	5	142
Roof Research Center	4	2	33.0	1	1	14.3	1	1	49.6	1	1	3.1	7	5	363
Neutron Scattering Facility	12	2	48.1	1	1	4.0	3	2	17.6	12	5	30.3	28	10	1,161
Totals (Experimenters % Use)	**411[d]**		**50.4[d]**	**337**		**30.4**	**84**		**13.0**	**64**		**6.2**	**896**		**16,871**

[a]Experimenters.
[b]Organizations.
[c]The totals for the NERP do not include 15,802 individuals in the Ecological and Physical Sciences Study Center who participated in research educational units days.
[d]Includes 338 ORNL users (42.5% of use).

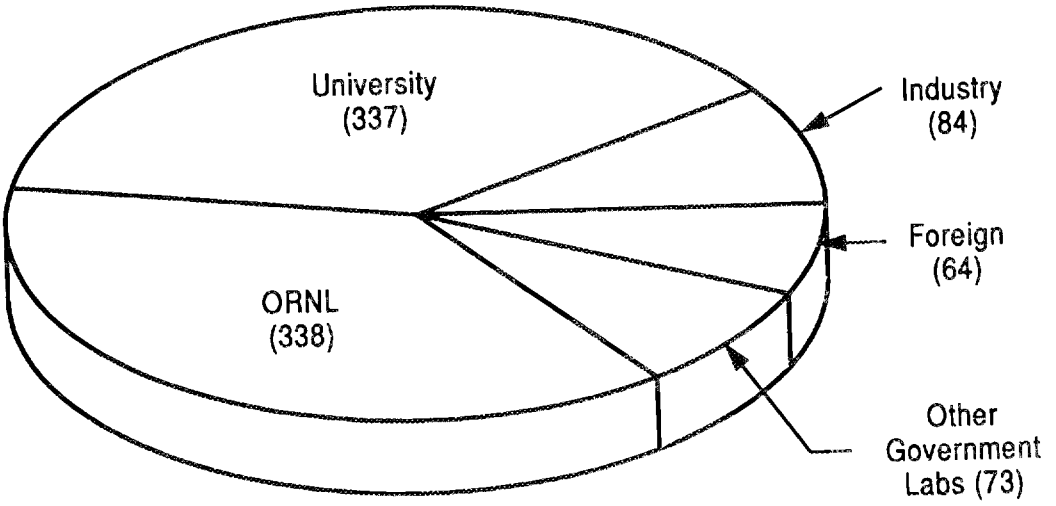


Fig. 7.6. Participants at ORNL user facilities.

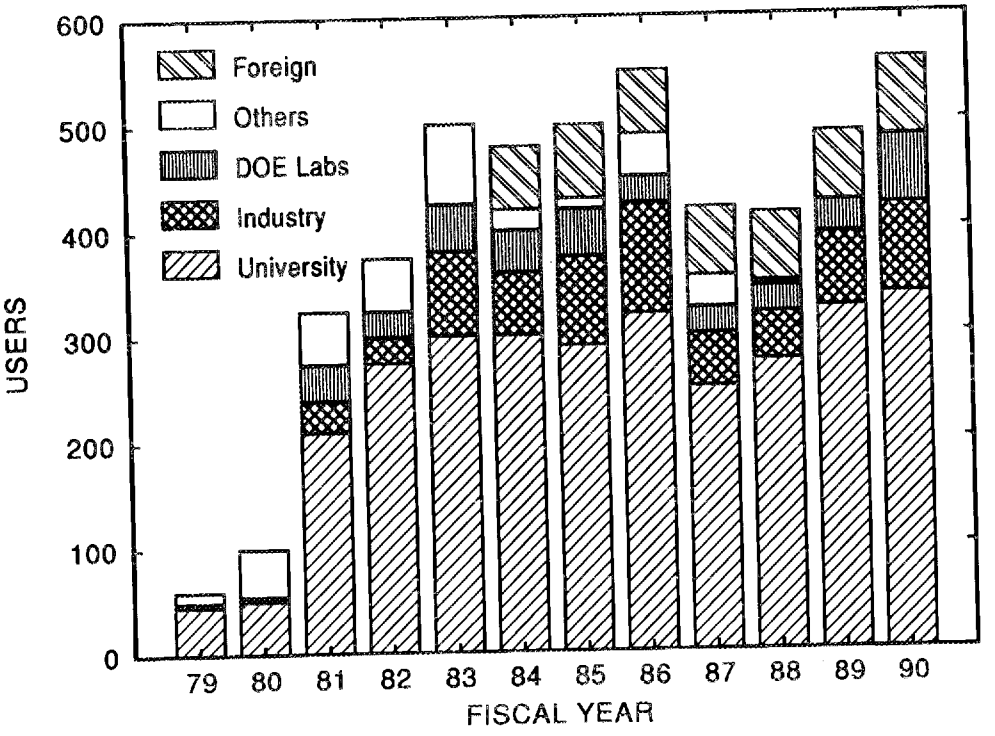


Fig. 7.7. Number of outside users at ORNL user facilities.

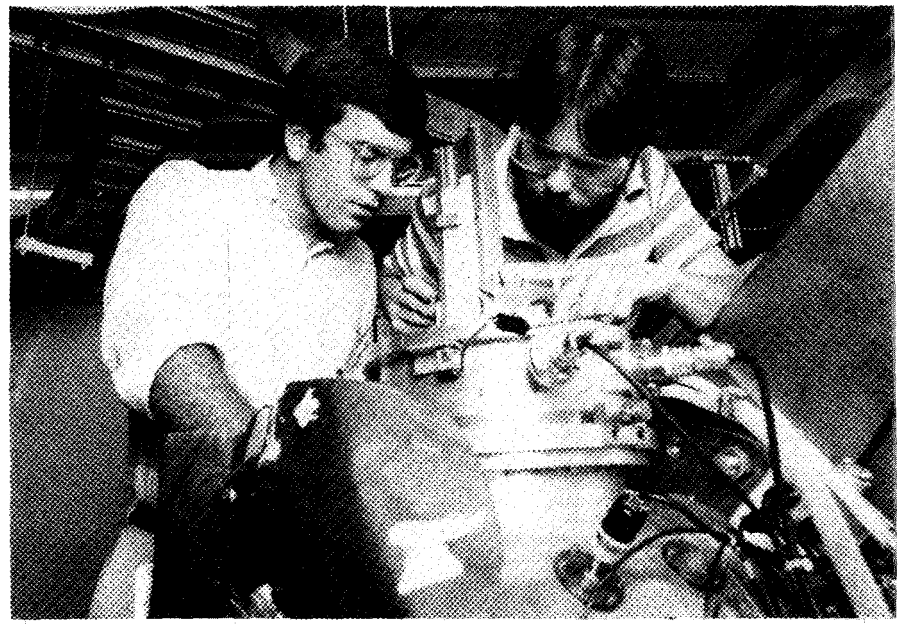


Fig. 7.8. Scientists from AT&T Bell Laboratories load the automatic sample changer at the High Flux Isotope Reactor before programming the 30-m small-angle neutron-scattering spectrometer for overnight operation. These participants in the ORNL User Program probed the structure of block copolymers.

Table 7.7. Number of guest assignments at ORNL

Research sector	Fiscal year						
	1984	1985	1986	1987	1988	1989	1990
University	628	920	967	1378	1428	1395	1551
Industry	260[a]	344[a]	398[a]	617	689	736	972
Federal agencies				39	40	52	52
Foreign institutions	97	83	77	62	59	48	84
Other	49	59	191	77	88	113	256
Total	**1034**	**1406**	**1633**	**2173**	**2304**	**2344**	**2915**

[a]Includes federal agencies.

Table 7.8. Percentage of total guest assignments at ORNL

Research sector	Fiscal year						
	1984	1985	1986	1987	1988	1989	1990
University	60.7	65.4	59.2	63.4	62.0	59.5	53.2
Industry	25.1[a]	24.5[a]	24.4[a]	28.4	29.9	31.4	33.3
Federal agencies				1.8	1.8	2.2	1.8
Foreign institutions	9.4	5.9	4.7	2.9	2.6	2.1	2.9
Other	4.7	4.2	11.7	3.5	3.8	4.8	8.8
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**

[a]Includes federal agencies.

8. human resources

8. Human Resources

Laboratory Personnel

The diverse nature of the work performed at Oak Ridge National Laboratory (ORNL) demands a high-quality, multidisciplinary technical staff and an equally skilled support and services staff. Scientists and engineers constitute the bulk of the Laboratory's professional staff, representing about 70% of the total number (Table 8.1). Of the 741 professional scientists on staff, 476 (or 64%) hold Ph.D.s. Among engineers, 252 of the 815 (or 31%) on staff hold Ph.D.s; master's degrees are held by another 370 (or 24%) professional scientists and engineers. About 88% of the total professional staff hold bachelor degrees or higher.

The engineering disciplines represented by our staff are primarily chemical, mechanical, and nuclear. There are also about 32 mathematicians, about 448 other physical scientists, about 234 life scientists (biomedical and environmental), and about 27 social scientists. ORNL is also supported by Martin Marietta Energy Systems, Inc. (Energy Systems) central organizations including Engineering; Computing and Telecommunications Division; Information Resources and

Table 8.1. ORNL staff composition (CY 1990)[a]

	Ph.D.	MS/MA	BS/BA	Other	Total
	Professional staff				
Scientists	476	133	117	15	741
Engineers	252	237	262	64	815
Management/administrative	110	81	101	34	326
Other	30	75	112	162	379
Total professional staff	**868**	**526**	**592**	**275**	**2261**
	Support staff				
Technicians	0	4	83	417	504
Union employees (includes crafts, laborers, etc.)	0	1	7	928	936
Administrative/clerical	0	1	61	626	688
Other (i.e., supervisors of union employees)	0	0	5	84	89
Total support staff	**0**	**6**	**156**	**2055**	**2217**
Laboratory total staff	**868**	**532**	**748**	**2330**	**4478**

[a]Includes full-time regular employees.

Administration, which includes library, technical publications, graphic arts, and printing support; and Procurement.

The average age of all ORNL employees is 43.8 years, and the average years of service is 14.6. The average age has remained stable since 1985 (from 43.4 years), while the length of service continues to decrease (from 15.1 years). In 1990, the number of new hires (485) failed to keep pace with the number of separations (495), resulting in an addition rate of 8.8% and a separation rate of 9.0%. In 1989 the addition rate was only slightly higher (7.6%) than the separation rate (7.5%). In 1987 and 1988, the addition rate (12.4% and 11.5% respectively) was significantly higher than the separation rate (6.7% and 8.4% respectively).

The Laboratory had an 81% acceptance rate for employment offers made to persons with Ph.D.s during 1990. This rate has increased from 72% in 1989. The acceptance rate for B.S. and M.S. candidates has also increased this year from 70% to 71%. However, the competition for outstanding scientists and engineers is increasing. To ensure the continued high caliber of those being hired, the Laboratory has established a set of hiring guidelines that defines the academic and professional characteristics being sought in new hires. Additionally, an ad hoc review process has been reinstituted for prospective Ph.D. new hires 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. 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. ORNL participates in Energy Systems annual awards night to recognize outstanding performance in various categories: publications, technical achievement, management support service, inventions, operational performance, and administrative/ technical support.

[illegible]

Numerous studies have addressed the changing demographics of the country's work force (e.g., *Workforce 2000*), 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 to adopt less traditional approaches to personnel management. It is projected that by the year 2000 more than half of those entering the work force will be women, minorities, or the disabled. The Laboratory, and Energy Systems as a whole, are already instituting some changes in personnel policies that will be required to meet the different demands of this changing work force. For example, the company's revised part-time policy and the concept of employee convenience time both allow employees greater flexibility in scheduling work hours. Additional work force issues are also being identified and considered by an Energy Systems and Martin Marietta Corporate task force. ORNL is also proposing enhanced recruiting and marketing efforts to target women and minorities (Table 8.2).

As mentioned earlier, disabled Americans will assume a greater role in the work force in the future. The Laboratory will continue its heightened emphasis on recruiting and hiring qualified disabled candidates. Energy Systems' President Clyde Hopkins, who is serving as a member of the Executive Committee of the (U.S.) President's Committee on the Employment of People with Disabilities, provides leadership in this area. Energy Systems recognizes the potential for significant change in our disability program overall relative to Affirmative Action (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 director of ORNL Human Resources. A primary

Table 8.2. Affirmative Action and Equal Employment Opportunity

Full-time regular and continuing part-time employees	Calendar year 1985				Calendar year 1990			
	Male	Female	Total	%	Male	Female	Total	%
U.S. Citizens								
White	2903	913	3816	89.7	2950	1123	4073	89.9
Black	196	128	324	7.6	205	127	332	7.3
Hispanic	24	3	27	0.6	23	6	29	0.6
Asian or Pacific Island	69	17	86	2.0	72	21	93	2.1
American Indian or Alaskan native	3	1	4	0.1	3	2	5	0.1
Total minorities	**292**	**149**	**441**	**10.3**	**303**	**156**	**459**	**10.1**
Total U.S. citizens	**3195**	**1062**	**4257**	**100**	**3253**	**1279**	**4532**	**100**
Foreign Nationals[a]			71		57			

[a]Includes full-time regular and temporary employees.

responsibility for the AA Program site manager is to monitor AA activities and to inform Laboratory management about progress made in hiring and promoting minorities and women. The site manager also monitors and keeps management aware of areas of concern relative to the program (e.g., the inability to meet a hiring goal or on-staff representation of minorities or of women that is below the calculated availability). Overall, the Laboratory's representation of minorities has remained fairly constant. The representation of women on staff has continued to increase, with a similar increase in upward mobility (i.e., in the numbers being promoted to higher levels and into management).

Upward mobility for minorities is receiving special attention from Laboratory management. The Laboratory has undertaken additional recruiting efforts to increase the size of the feeder 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. This year eight ORNL employees, primarily women and minorities, participated in the program. The program provides an opportunity for each participant to become better acquainted with the larger Energy Systems organization. Hopefully, through the interactions necessitated by these mentorships, employees will gain additional insights that will be useful in developing their own career plans.

Among 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 1990 more than 800 employees participated in the Educational Assistance Program.

This 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. In addition, the Laboratory is responding to a heightened emphasis on environmental, safety, and health issues by expanding specialized technical training programs. Finally, the cadre 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 cultural diversity. This area of management training is crucial in preparing managers for the changing work force that will be emerging in the 1990s.

9. site and facilities

9. Site and Facilities

Laboratory Description

Oak Ridge National Laboratory (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 utilization 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 facilities' responsibility for its main site and 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 as well as the use of local off-site rental space.

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 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 general plant project 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. However, much more must be accomplished to provide the kind of facilities conducive to producing the highest quality research programs.

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 decontamination and decommissioning. 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

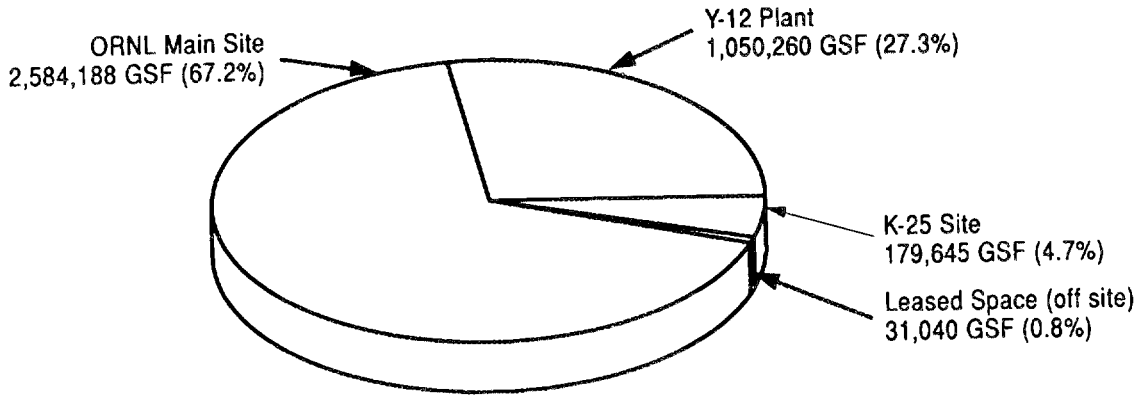


Fig. 9.1. Laboratory space distribution—location and building area in gross square feet (GSF).

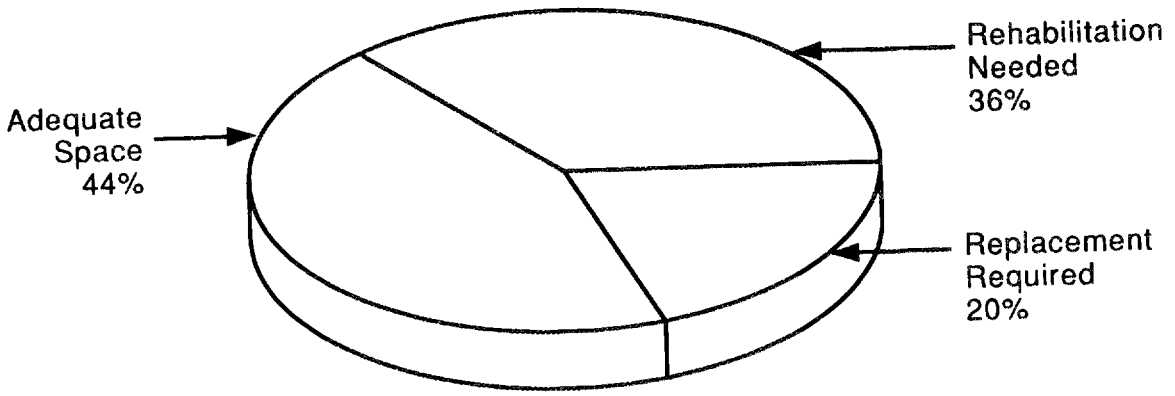


Fig. 9.2. Condition of Laboratory space by percentage.

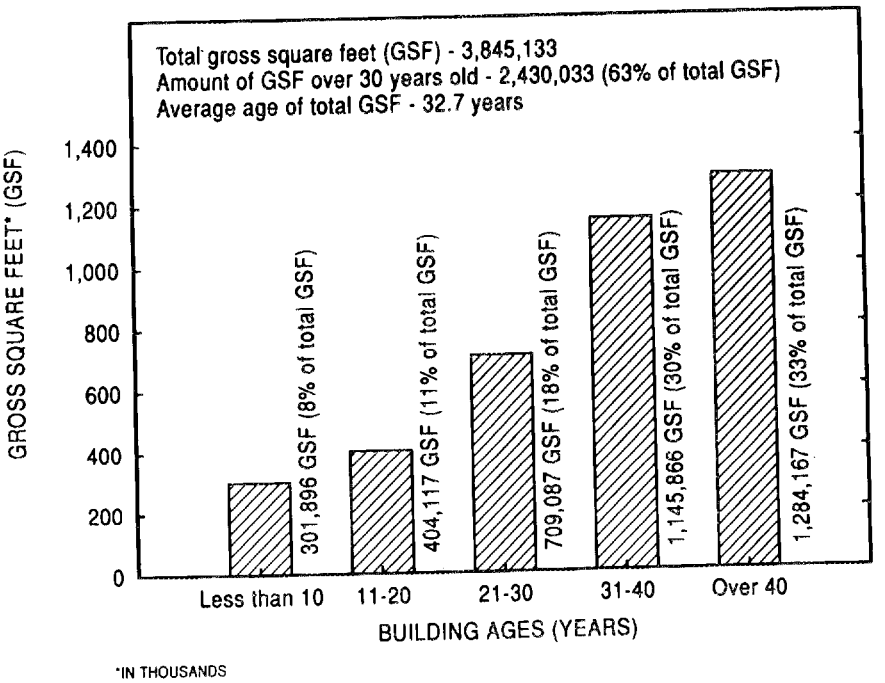


Fig. 9.3. Gross square footage of Laboratory buildings—categorized by age.

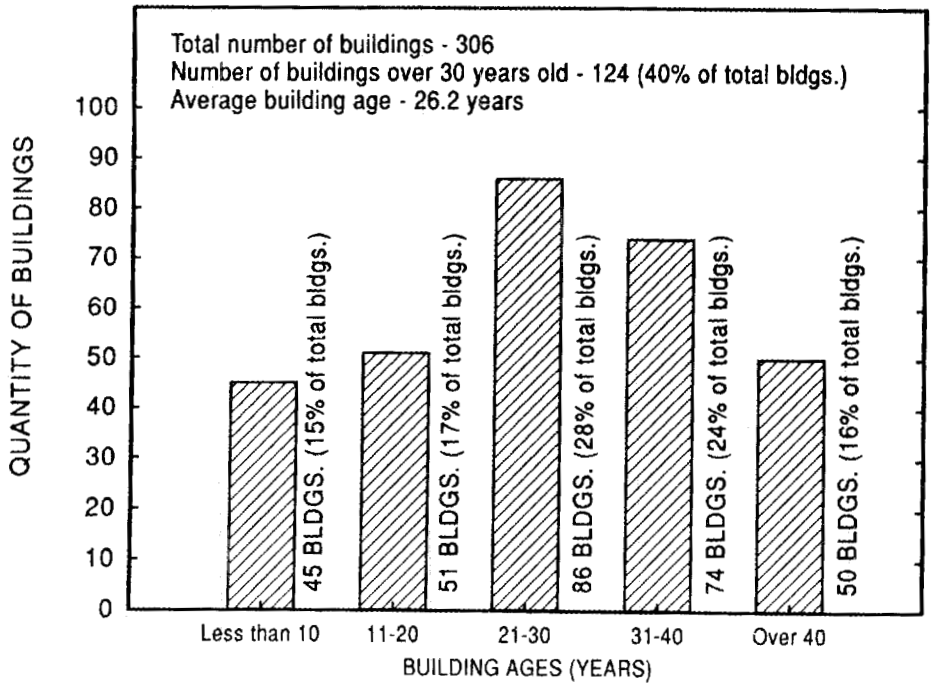


Fig. 9.4. Distribution of Laboratory buildings by age.

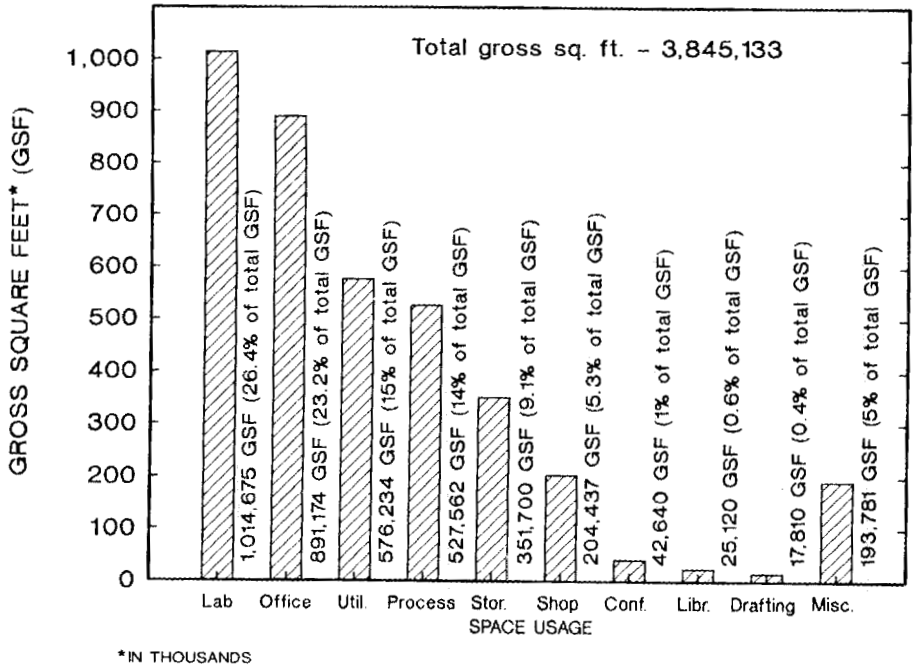


Fig. 9.5. Use of Laboratory space.

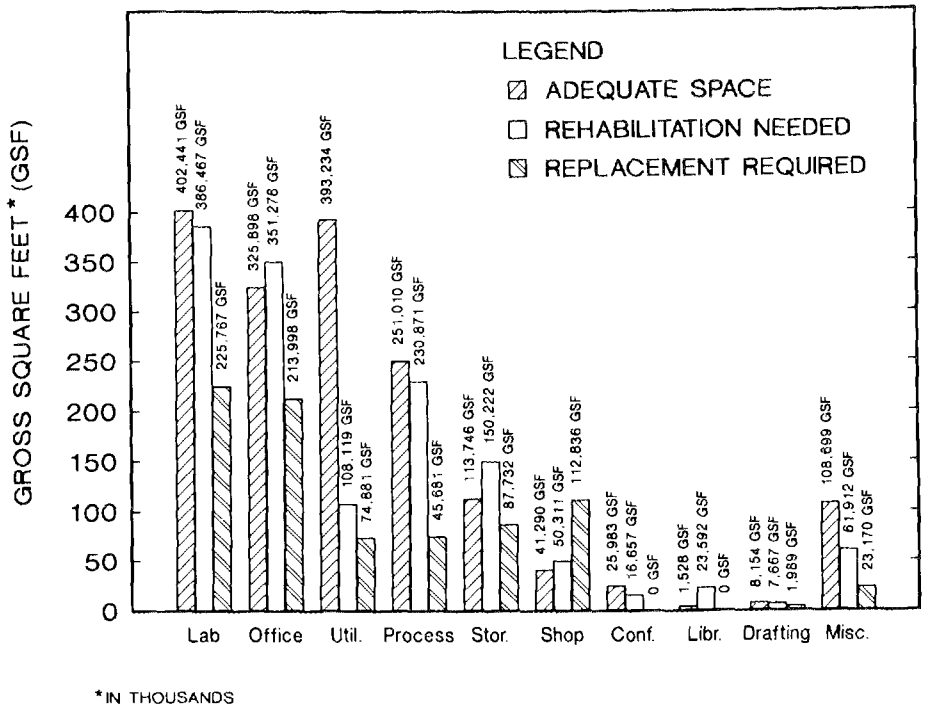


Fig. 9.6. Condition of Laboratory space—categorized by use.

nonenvironmental capital improvements at ORNL has declined by 45% between FY 1984 and FY 1991.

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 research and development (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:

- an Advanced Neutron Source 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
- a Materials Science and Engineering 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.

Table 9.1. Estimated facilities replacement value

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 1991 dollars.

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:

- an Advanced Computing Technology Center to provide a first-class computing capability to support research programs; and
- a Technology Transfer Center 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 over the past 40-plus 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 decommissioning and demolition of the reactor and isotope facilities as part of DOE's

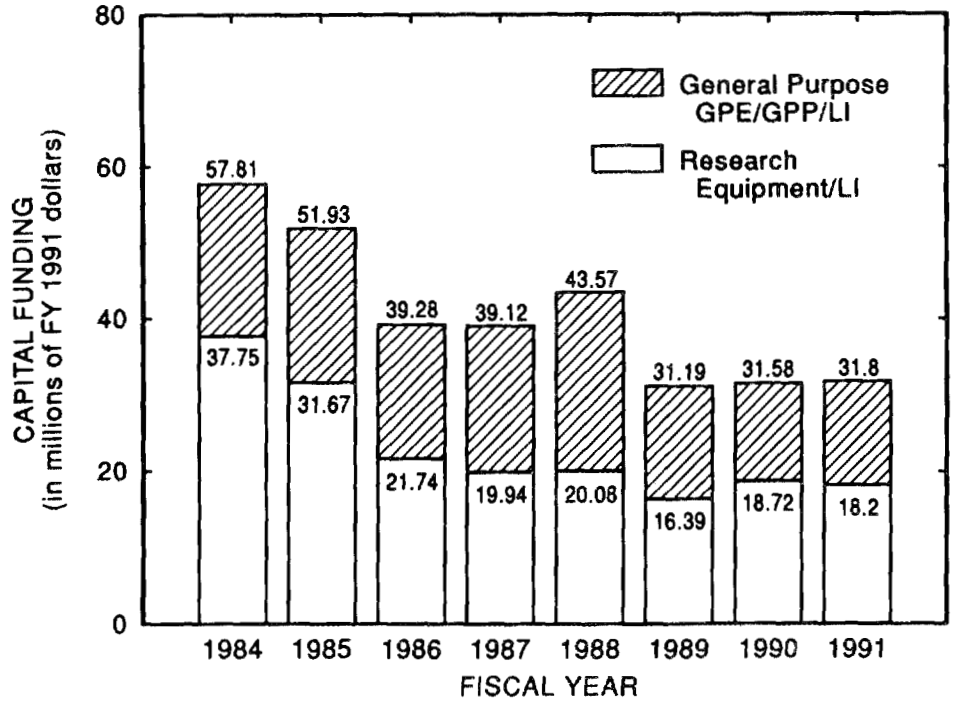


Fig. 9.7. Recent capital-funding levels for nonenvironmental capital improvements at ORNL

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.

Facilities Resource Requirements

As the Laboratory's site and facilities planning staff progress in the preparation of a comprehensive ORNL Site Development Plan, many of the Laboratory's construction project needs are being identified. A current list of major construction projects is presented in Table 9.2. These construction activities would provide a major step in ORNL's site and facilities modernization efforts.

In addition to ORNL's proposed line-item construction projects, other critical elements of the Laboratory's modernization program are (1) general plant projects (GPPs), (2) general-purpose equipment (GPE), and (3) management and eventual decommissioning and demolition of surplus facilities.

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 Office of Energy Research (ER) GPP funding totaling the levels shown in Table 9.3.

Table 9.2. Major construction projects[a]
($ in millions)

	Fiscal year								
	Funded construction		Budgeted construction	Proposed construction					Total estimated cost[b]
	1990	1991	1992	1993	1994	1995	1996	1997	
Research program line-item projects[c]									
Advanced Neutron Source (design phase)				38.9					38.9
Advanced Neutron Source (construction)					*d*	*d*	*d*	*d*	800–900
Center for Biological Sciences				20.0	45.0	40.0	5.0		110.0
Earth Systems Laboratory					2.0	7.0	3.0		12.0
Advanced Environmental Photonics Laboratory						1.5	6.5		8.0
Center for Study of Advanced Materials					2.0	14.0			16.0
Solid State Research Laboratory						3.5	14.5	10.0	28.0
Center for Advanced Microstructural Analysis					3.0	12.0	14.5	8.0	37.5
Composite Materials Laboratory					*d*	*d*	*d*		30.0
Environmental compliance and waste management projects									
Bethel Valley LLW-CAT system upgrade (WBS 3.37)	10.4	7.9	0.10						35.0
Melton Valley LLW-CAT system upgrade (WBS 3.45)			4.5	15.9	11.5	9.1			41.0
Waste Characterization and Certification Facility (WBS 4.48)					3.0	10.0	4.0		17.0
Bethel Valley FFA upgrades (WBS 3.31)					7.0	15.0	15.0	8.0	45.0
MVST Capacity Increase (WBS 3.46)					15.0	10.0	10.0	5.0	40.0
Waste Handling and Packaging Plant (WBS 4.13)						33.0	62.0	107.0	255.0
Pretreatment System for Decontamination of Waste Water (WBS 3.36)						3.0	7.0	5.0	15.0
LLW FFA Upgrade WBS 3.04)						5.0	15.0	15.0	35.0
Decontamination Facility (WBS 3.76)							3.0	11.1	22.1
Dry Cask Storage (WBS 4.61)							4.0	12.0	25.0

Table 9.2 (continued)

	Fiscal year								
	Funded construction		Budgeted construction	Proposed construction					Total estimated cost[b]
	1990	1991	1992	1993	1994	1995	1996	1997	
Multiprogram general-purpose facilities (KG)									
Buildings/facilities/revitalization									
A. Replace substandard housing									
Measurements and Controls Support Facility	0.89	3.08		0.46					4.4
Central Research and Support Building				1.0	3.0	6.0	2.4		12.4
Maintenance Support and Decontamination Laundry Facility					4.0	15.0	10.0	4.0	33.0
Safeguards and Security Building								3.0	15.0
B. Renovate serviceable structures									
Replace deteriorated roofing, priority 1				5.0	6.0	4.0			15.0
Replace deteriorated roofing, priority 2						3.0	7.5	6.0	16.5
Replace deteriorated roofing, priority 3								3.0	18.0
Restore Central Research Complex						10.0	20.0	20.0	60.0
Upgrade building HVAC systems, east end					3.0	9.0	3.0		15.0
Upgrade building HVAC systems, west end						5.0	10.0	10.0	25.0
Refurbish metallurgical hot cells								6.0	50.0

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

Table 9.2 (continued)

	Fiscal year								
	Funded construction		Budgeted construction	Proposed construction					Total estimated cost[b]
	1990	1991	1992	1993	1994	1995	1996	1997	
C. Upgrade capabilities									
Advanced Computing Technology Center					3.0	7.0	5.0		15.0
Technology Transfer Center								4.0	20.0
Environmental, safety, and health protection									
A. Environmental protection									
Replace oil-filled transformers					2.0	3.0			5.0
Steam plant environmental improvements						4.0	8.0	5.0	17.0
B. Safety									
Road safety improvements	0.87								2.5
Fire protection upgrade	1.29	2.0	0.01						3.3
Health physics instrumentation upgrade				14.0	4.7				18.7
OSHA compliance facility upgrades (priority 1)					5.0	8.0	7.0		20.0
OSHA compliance facility upgrades (priority 2)						10.0	20.0	20.0	80.0
OSHA compliance facility upgrades (priority 3)							10.0	25.0	100.0
C. Health protection									
Radiation Exposure Assessment Laboratory				3.0	8.0	14.0	14.0	2.0	41.0

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 approximately $3 million to $3.5 million annually for GPE of approximately $7 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,

Table 9.2 (continued)

	Fiscal year								
	Funded construction		Budgeted construction	Proposed construction					Total estimated cost[b]
	1990	1991	1992	1993	1994	1995	1996	1997	
Utility restorations									
Electrical system upgrade	0.84	1.45	0.01						2.3
Upgrade steam distribution system, west end			1.08	5.02		2.90			9.0
Upgrade sanitary sewerage system				2.0	7.0	7.0			16.0
Upgrade water system					3.0	12.0	7.0		22.0
Upgrade primary electrical distribution system						3.0	8.0	7.0	18.0

[a]Construction data as of November 1, 1990, for research program and environmental compliance projects and November 16, 1990, for multiprogram general-purpose facilities.

[b]Total estimated cost is tentative until conceptual design report has been completed on each project.

[c]Does not include accelerator and reactor improvements and modifications projects or New Production Reactor construction funding.

[d]To be determined.

[e]Joint initiative with Southeastern University Research Association.

Table 9.3. General plant project funding from Landlord Programs ($ in millions—BA)

	Fiscal year						
	1991	1992	1993	1994	1995	1996	1997
Funding	6.1	6.4	24.4	24.4	24.4	24.4	24.4

Table 9.4. General-purpose equipment funding from Landlord Programs ($ in millions—BA)

	Fiscal year						
	1991	1992	1993	1994	1995	1996	1997
Funding	3.1	13.1	7.7	7.7	7.7	7.7	7.7

and other items related to the general operation and upkeep of ORNL.

Decommissioning and Demolition Projects

Surplus Facilities

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 surveillance and maintenance (S&M) of 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 9.5 and 9.6 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 decontamination and decommissioning (D&D), which is expected to be orders of magnitude higher.

Table 9.5. 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 9.6. 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.

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 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.

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

[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.

among the best in the country." Increasingly, the missions of ORNL are dependent on computing resources and computing expertise. Consequently, the plan is designed to both remedy shortcomings and to step out aggressively to provide ORNL researchers with a competitive advantage in computing resources.

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 Martin Marietta Energy Systems Computing and Telecommunications Division (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 network-limited.

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.

At the end of FY 1990, 34 computing goals were established. Some of the goals that were achieved during FY 1991 are the following:

- formed a "Partnership for Computational Science" and submitted a proposal to DOE,
- installed an FDDI network connecting six buildings,
- established a Workstation Support Center,
- allocated time on the Cray XMP,
- provided grants for use of the Cray XMP and Intel iPSC/860 systems,
- developed a prototype network central file system,
- increased automation of computer operations,
- procured improvements to the Visualization Laboratory, and
- automated computer authorization.

10. resource projections

10. Resource Projections

The Laboratory 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; and
- Table 10.6, Laboratory funding summary of environmental, safety, and health activities.

Tables 10.1, 10.3, and 10.5 report funding in millions of dollars. These Laboratory resource projections are budget authorizations (BA). BA reported in the tables reflect new BA requirements as requested in the FY 1993 budget submission document 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. The inflation escalation factor in BA dollars for both FY 1992 and FY 1993 is 4.5%. Figures for FY 1994 through FY 1997 are reported in constant FY 1993 dollars.

Personnel statistics are reported as the number of full-time equivalent (FTE) employees in Tables 10.2 and 10.4.

The estimated costs for all environmental, safety, and health activities are reported in Table 10.6.

Table 10.1. Laboratory funding summary
($ in millions—BA)[a]

	Fiscal year							
	1990	1991	1992	1993	1994	1995	1996	1997
DOE effort	364.2	369.2	553.2[b]	656.1[b]	647.3	657.3	667.7	678.2
Work for Others[c]	87.2	88.9	110.6	116.1	115.9	116.0	116.1	116.2
Total operating	**451.4**	**458.1**	**663.8**	**772.2**	**763.2**	**773.3**	**783.8**	**794.4**
Capital equipment	16.6	13.0	14.8	36.6	35.3	36.1	36.5	37.3
Construction	11.7	19.9	8.1	8.8	8.8	7.0	3.5	0.0
General-purpose facilities Funded/budgeted	16.9	6.5	0.0	0.0	0.0	0.0	0.0	0.0
General plant projects	6.0	6.1	6.4	24.4	24.4	24.4	24.4	24.4
General-purpose equipment	3.0	3.1	13.1	7.7	7.7	7.7	7.7	7.7
Total Laboratory	**505.6**	**506.7**	**706.2**	**849.7**	**839.4**	**848.5**	**855.9**	**863.8**
Proposed construction			9.5	109.6	156.4	310.3	339.8	206.6
Total projected funding	**505.6**	**506.7**	**715.7**	**959.3**	**995.8**	**1158.8**	**1195.7**	**1070.4**

[a]Inflation escalation factor for FY 1992 and FY 1993 is 4.5%. Figures for FY 1994 through FY 1997 are in constant FY 1993 dollars. BA in table is new BA requirement as requested in the FY 1993 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 1993 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. In 1990, about $5.3 million of ORNL-managed WFO was reported through the other two financial plans and is not included in the above table.

Table 10.2. Laboratory personnel summary
[Full-time equivalents (FTEs)]

	Fiscal year							
	1990	1991	1992	1993	1994	1995	1996	1997
Direct DOE effort	1415	1564	1919	2119	2103	2138	2175	2213
Work for Others[a]	331	383	375	376	375	375	375	376
Total technical direct	**1746**	**1947**	**2294**	**2495**	**2478**	**2513**	**2550**	**2589**
Other direct	205	264	364	411	408	412	416	419
Total direct personnel	**1951**	**2211**	**2658**	**2906**	**2886**	**2925**	**2966**	**3008**
Indirect personnel	2576	2650	2650	2700	2700	2700	2700	2700
Total Laboratory	**4527**	**4861**	**5308**	**5606**	**5586**	**5625**	**5666**	**5708**

[a]Includes Nuclear Regulatory Commission.

Table 10.3. Funding by assistant secretarial level office
($ in millions—BA)[a]

	Fiscal year							
	1990	1991	1992	1993	1994	1995	1996	1997
Office of Energy Research[b,c]								
Operating expense	141.5	156.4	210.7	276.5	283.9	291.9	300.1	308.6
Capital equipment[c]	14.2	10.1	18.8	32.5	33.3	34.2	35.0	36.1
Construction[c]	24.4	9.3	0.0	24.4	24.4	24.4	24.4	24.4
Total[c]	**180.1**	**175.8**	**229.5**	**333.4**	**341.6**	**350.5**	**359.5**	**369.1**
Assistant Secretary for Nuclear Energy								
Operating expense	46.9	36.3	52.3	51.0	51.8	52.7	53.6	54.5
Capital equipment	1.4	0.7	1.5	1.7	1.7	1.7	1.7	1.7
Total	**48.3**	**37.0**	**53.8**	**52.7**	**53.5**	**54.4**	**55.3**	**56.2**
Office of New Production Reactors[d]								
Operating expense	10.2	(0.7)[e]	0.0	0.0	0.0	0.0	0.0	0.0
Capital equipment	0.0	1.2	0.4	1.1	1.1	0.9	0.4	0.0
Construction	6.7	9.2	8.1	8.8	8.8	7.0	3.5	0.0
Total	**16.9**	**9.7**	**8.5**	**9.9**	**9.9**	**7.9**	**3.9**	**0.0**
Office of Civilian Radioactive Waste Management								
Operating expense	7.1	8.7	11.4	11.9	12.2	12.7	13.4	13.9
Capital equipment	0.0	0.0	0.0	2.2	0.0	0.0	0.0	0.0
Total	**7.1**	**8.7**	**11.4**	**14.1**	**12.2**	**12.7**	**13.4**	**13.9**
Assistant Secretary for Defense Programs[c]								
Operating expense	7.7	7.4	11.2	12.2	12.8	13.4	14.0	14.6
Capital equipment	0.4	0.4	1.8	2.0	2.1	2.2	2.3	2.4
Total[c]	**8.1**	**7.8**	**13.0**	**14.2**	**14.9**	**15.6**	**16.3**	**17.0**
Assistant Secretary for Conservation and Renewable Energy								
Operating expense	47.0	57.9	75.8	86.2	87.1	87.1	87.1	87.1
Capital equipment	2.3	3.6	5.2	4.7	4.7	4.7	4.7	4.7
Total	**49.3**	**61.5**	**81.0**	**90.9**	**91.8**	**91.8**	**91.8**	**91.8**

Table 10.3 (continued)

	Fiscal year							
	1990	1991	1992	1993	1994	1995	1996	1997
Assistant Secretary for Fossil Energy								
Operating expense	6.3	6.6	7.4	9.6	9.6	9.6	9.6	9.6
Capital equipment	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Total	**6.3**	**6.7**	**7.5**	**9.6**	**9.6**	**9.6**	**9.6**	**9.6**
Assistant Secretary for Environment, Safety, and Health								
Operating expense	4.6	6.9	5.6	5.2	5.2	5.2	5.2	5.2
Capital equipment	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Total	**4.6**	**6.9**	**5.7**	**5.3**	**5.3**	**5.3**	**5.3**	**5.3**
Office of Environmental Restoration and Waste Management[f]								
Operating expense	49.8	12.9	58.2	18.8	0.0	0.0	0.0	0.0
Capital equipment	1.3	3.1	13.1	0.0	0.0	0.0	0.0	0.0
Construction	2.7	6.1	6.4	0.0	0.0	0.0	0.0	0.0
Total	**53.8**	**22.1**	**77.7**	**18.8**	**0.0**	**0.0**	**0.0**	**0.0**
Energy Information Administration								
Operating expense	1.0	1.0	1.3	1.4	1.4	1.4	1.4	1.4
Office of Administration and Human Resource Management								
Operating expense	0.1	0.4	0.2	0.2	0.2	0.2	0.2	0.2
Construction[c]	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total[c]	**0.9**	**0.4**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**
Office of Policy, Planning, and Analysis								
Operating expense	1.2	2.1	3.0	2.5	2.5	2.5	2.5	2.5
Federal Energy Regulatory Commission								
Operating expense	0.0	0.6	2.5	2.5	2.5	2.5	2.5	2.5
Assistant Secretary for International Affairs and Energy Emergencies								
Operating expense	0.1	0.0	0.2	0.2	0.2	0.2	0.2	0.2

Table 10.3 (continued)

	Fiscal year							
	1990	1991	1992	1993	1994	1995	1996	1997
DOE Funding from Energy Systems Central Organizations								
Operating expense	7.8	48.1	84.5	146.4	146.4	146.4	146.4	146.4
Construction	0.0	7.9	0.0	0.0	0.0	0.0	0.0	0.0
Total program	**7.8**	**56.0**	**84.5**	**146.4**	**146.4**	**146.4**	**146.4**	**146.4**
Subtotal DOE Programs								
Operating expense	331.3	382.3	523.0	624.5	562.3	572.1	582.5	593.2
Capital equipment[c]	19.6	18.5	26.9	43.2	41.9	42.7	43.2	43.9
Funded/budgeted construction	34.6	32.5	8.1	8.8	0.0	0.0	0.0	0.0
Total[c]	**385.5**	**433.3**	**558.0**	**676.5**	**604.2**	**614.8**	**625.8**	**637.1**
DOE Contractors and Operations Offices								
Operating expense	32.9	24.6	28.9	31.5	31.5	31.5	31.5	31.5
Total DOE Programs [b,c,f]								
Operating expense	364.2	369.2	553.2	656.1	647.3	657.3	667.7	678.2
Capital equipment[c]	19.6	16.1	27.9	44.3	43.0	43.8	44.2	45.0
Construction[c]	34.6	32.5	14.5	33.2	33.2	31.4	27.9	24.4
Total DOE programs[c]	**418.4**	**417.8**	**595.6**	**733.6**	**723.5**	**732.5**	**739.8**	**747.6**
Nuclear Regulatory Commission								
Operating expense	17.2	15.1	18.0	16.9	16.9	16.9	16.9	16.9
Department of Defense								
Operating expense	45.8	40.6	58.5	65.8	65.8	65.8	65.8	65.8
Other Federal Agencies								
Operating expense	18.3	21.7	27.8	28.0	27.8	27.9	28.0	28.1
Other Work for Others								
Operating expense	5.9	11.5	6.3	5.4	5.4	5.4	5.4	5.4

Table 10.3 (continued)

	Fiscal year							
	1990	1991	1992	1993	1994	1995	1996	1997
Total Work for Others								
Operating expense	87.2	88.9	110.6	116.1	115.9	116.0	116.1	116.2
Total Laboratory[b]								
Operating expense	451.4	458.1	663.8	772.2	763.2	773.3	783.8	794.4
Capital equipment	16.6	13.0	14.8	36.6	35.3	36.1	36.5	37.3
Construction	11.7	19.9	8.1	8.8	8.8	7.0	3.5	0.0
General-purpose equipment	3.0	3.1	13.1	7.7	7.7	7.7	7.7	7.7
General plant project	6.0	6.1	6.4	24.4	24.4	24.4	24.4	24.4
General-purpose facilities	16.9	6.5	0.0					
Total	**505.6**	**506.7**	**706.2**	**849.7**	**839.4**	**848.5**	**855.9**	**863.8**
Proposed construction	0.0	0.0	9.5	109.6[g]	156.4	310.3	339.8	206.6
Total projected funding	**505.6**	**506.7**	**715.7**	**959.3**	**995.8**	**1158.8**	**1195.7**	**1070.4**

[a]Inflation escalation factor for FY 1992 and FY 1993 is 4.5%. Figures for FY 1994 through FY 1997 are in constant FY 1993 dollars. BA in table is new BA requirements as requested in the FY 1993 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 1993 data include several field work proposals (FWPs) included in the 1993 budget submission to fund Occupational Safety and Health Administration (OSHA) and other safety and health compliance needs.

[c]Includes some general plant projects and/or general-purpose equipment funding.

[d]Does not include DOE new production reactor (DOE-NP) funding via transfers from other DOE laboratories.

[e]Parentheses contain negative amounts, indicating a budgetary deficit.

[f]FY 1992 data include several FWPs included in the 1993 budget submission to fund OSHA and other safety and health compliance needs.

[g]Includes $24.4 million proposed general plant project funding.

Table 10.4. Personnel by assistant secretarial [illegible]
[Full-time equivalents (FTEs)]

	Fiscal year							
	1990	1991	1992	1993	1994	1995	1996	1997
Office of Energy Research								
Technical personnel	651.4	654.0	763.9	902.2[a]	930.2	959.4	990.2	1022.4
Other direct personnel	83.4	92.2	115.6	128.2[a]	129.5[a]	131.1	132.5	134.1
Total direct personnel	**734.8**	**746.2**	**879.5**	**1030.4[a]**	**1059.7**	**1090.5**	**1122.7**	**1156.5**
Assistant Secretary for Nuclear Energy								
Technical personnel	178.3	178.8	206.1	193.2	196.0	198.9	202.0	205.2
Other direct personnel	18.7	40.8	59.4	53.6	55.6	57.7	59.9	62.2
Total direct personnel	**197.0**	**219.6**	**265.5**	**246.8**	**251.6**	**256.6**	**261.9**	**267.4**
Office of New Production Reactors								
Technical personnel	59.2	1.1	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**60.9**	**1.1**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Office of Civilian Radioactive Waste Management								
Technical personnel	14.3	11.4	17.2	17.8	18.0	18.2	18.4	18.6
Other direct personnel	2.0	4.0	4.7	4.6	4.6	4.6	4.7	4.7
Total direct personnel	**16.3**	**15.4**	**21.9**	**22.4**	**22.6**	**22.8**	**23.1**	**23.3**
Assistant Secretary for Defense Programs								
Technical personnel	42.4	40.8	60.5	55.1	57.5	60.1	62.8	65.6
Other direct personnel	2.2	1.1	2.7	2.4	2.5	2.6	2.7	2.8
Total direct personnel	**44.6**	**41.9**	**63.2**	**57.5**	**60.0**	**62.7**	**65.5**	**68.4**
Assistant Secretary for Conservation and Renewable Energy								
Technical personnel	136.9	130.2	160.9	180.3	179.6	179.6	179.6	179.6
Other direct personnel	1.5	4.1	9.3	3.6	3.6	3.6	3.6	3.6
Total direct personnel	**138.4**	**134.3**	**170.2**	**183.9**	**183.2**	**183.2**	**183.2**	**183.2**

Table 10.4 (continued)

	Fiscal year							
	1990	1991	1992	1993	1994	1995	1996	1997
Assistant Secretary for Fossil Energy								
Technical personnel	20.6	18.9	23.6	24.0	24.0	24.0	24.0	24.0
Other direct personnel	0.1	0.4	0.2	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**20.7**	**19.3**	**23.8**	**24.0**	**24.0**	**24.0**	**24.0**	**24.0**
Assistant Secretary for Environment, Safety, and Health								
Technical personnel	15.1	14.8	18.7	16.2	16.2	16.2	16.2	16.2
Other direct personnel	4.2	1.1	0.8	0.6	0.6	0.6	0.6	0.6
Total direct personnel	**19.3**	**15.9**	**19.5**	**16.8**	**16.8**	**16.8**	**16.8**	**16.8**
Office of Environmental Restoration and Waste Management								
Technical personnel	131.8	42.6	148.7[a]	48.4	0.0	0.0	0.0	0.0
Other direct personnel	19.3	5.0	22.7	6.6	0.0	0.0	0.0	0.0
Total direct personnel	**151.1**	**47.6**	**171.4**	**55.0**	**0.0**	**0.0**	**0.0**	**0.0**
Energy Information Administration								
Technical personnel	2.1	2.5	3.0	3.3	3.3	3.3	3.3	3.3
Other direct personnel	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**2.2**	**2.5**	**3.0**	**3.3**	**3.3**	**3.3**	**3.3**	**3.3**
Assistant Secretary for Management and Administration								
Technical personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	0.8	0.9	0.3	0.3	0.3	0.3	0.3	0.3
Total direct personnel	**0.8**	**0.9**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**
Office of Policy, Planning, and Analysis								
Technical personnel	2.5	6.8	11.6	9.1	9.1	9.1	9.1	9.1
Other direct personnel	0.0	0.4	0.4	0.1	0.1	0.1	0.1	0.1
Total direct personnel	**2.5**	**7.2**	**12.0**	**9.2**	**9.2**	**9.2**	**9.2**	**9.2**

Table 10.4 (continued)

	Fiscal year							
	1990	1991	1992	1993	1994	1995	1996	1997
Federal Energy Regulatory Commission								
Technical personnel	0.3	2.8	17.0	16.0	16.0	16.0	16.0	16.0
Other direct personnel	0.0	0.0	0.2	0.2	0.2	0.2	0.2	0.2
Total direct personnel	**0.3**	**2.8**	**17.2**	**16.2**	**16.2**	**16.2**	**16.2**	**16.2**
Assistant Secretary for International Affairs and Energy Emergencies								
Technical personnel	0.1	0.4	0.8	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	**0.1**	**0.4**	**0.8**	**0.9**	**0.9**	**0.9**	**0.9**	**0.9**
DOE Funding from Energy Systems Central Organizations								
Technical personnel	13.7	268.0	308.5	480.4	480.4	480.4	480.4	480.4
Other direct personnel	11.5	36.5	69.6	129.2	129.2	129.2	129.2	129.2
Total direct personnel	**25.2**	**304.5**	**378.1**	**609.6**	**609.6**	**609.6**	**609.6**	**609.6**
Subtotal DOE Programs								
Technical personnel	1268.7	1373.1	1740.5	1946.9	1931.2	1966.1	2002.9	2041.3
Other direct personnel	145.5	186.5	285.9	329.4	326.2	330.0	333.8	337.8
Total direct personnel	**1414.2**	**1559.6**	**2026.4**	**2276.3**	**2257.4**	**2296.1**	**2336.7**	**2379.1**
DOE Contractors and Operations Offices								
Technical personnel	146.0	191.0	178.3	171.7	171.7	171.7	171.7	171.7
Other direct personnel	23.8	24.9	31.7	39.7	39.7	39.7	39.7	39.7
Total direct personnel	**169.8**	**215.9**	**210.0**	**211.4**	**211.4**	**211.4**	**211.4**	**211.4**
Total DOE Programs								
Technical personnel	1414.7	1564.1	1918.8	2118.8	2102.9	2137.8	2174.6	2213.0
Other direct personnel	169.3	211.4	317.6	369.1	365.9	369.7	373.5	377.5
Total direct personnel	**1584.0**	**1775.5**	**2236.4**	**2487.8**	**2468.8**	**2507.5**	**2548.1**	**2590.5**

Table 10.4 (continued)

	Fiscal year							
	1990	1991	1992	1993	1994	1995	1996	1997
	Work for Others							
Nuclear Regulatory Commission								
Technical personnel	55.5	64.7	62.3	54.6	54.6	54.6	54.6	54.6
Other direct personnel	11.7	17.7	16.7	16.3	16.3	16.3	16.3	16.3
Total direct personnel	**67.2**	**82.4**	**79.0**	**70.9**	**70.9**	**70.9**	**70.9**	**70.9**
Department of Defense								
Technical personnel	165.4	190.4	198.7	215.6	215.6	215.6	215.6	215.6
Other direct personnel	17.6	21.3	11.1	5.0	5.0	5.0	5.0	5.0
Total direct personnel	**183.0**	**211.7**	**209.8**	**220.6**	**220.6**	**220.6**	**220.6**	**220.6**
Other Federal Agencies								
Technical personnel	88.8	92.9	92.0	88.1	86.4	86.8	87.2	87.6
Other direct personnel	5.3	12.4	18.0	20.2	20.2	20.2	20.2	20.2
Total direct personnel	**94.1**	**105.3**	**110.0**	**108.3**	**106.6**	**107.0**	**107.4**	**107.8**
Other Work for Others								
Technical personnel	21.5	35.1	22.0	18.0	18.0	18.0	18.0	18.0
Other direct personnel	1.3	1.4	1.0	0.6	0.6	0.6	0.6	0.6
Total direct personnel	**22.8**	**36.5**	**23.0**	**18.6**	**18.6**	**18.6**	**18.6**	**18.6**
Total Work for Others								
Technical personnel	331.2	383.1	375.0	376.3	374.6	375.0	375.4	375.8
Other direct personnel	35.9	52.8	46.8	42.1	42.1	42.1	42.1	42.1
Total direct personnel	**367.1**	**435.9**	**421.8**	**418.4**	**416.7**	**417.1**	**417.5**	**417.9**

Table 10. [illegible]

	Fiscal year							
	1990	1991	1992	1993	1994	1995	1996	1997
Total Laboratory Personnel								
Technical personnel[a]	1746	1947	2294	2495	2478	2513	2550	2589
Other direct personnel	205	264	364	411	408	412	416	419
Total Laboratory direct personnel	**1951**	**2211**	**2658**	**2906**	**2886**	**2925**	**2966**	**3008**
Total Laboratory indirect personnel	2576	2650	2650	2700	2700	2700	2700	2700
Total Laboratory personnel	**4527**	**4861**	**5308**	**5606**	**5586**	**5625**	**5666**	**5708**

[a]Includes several field-work proposals included in FY 1993 budget submission to fund Occupational Safety and Health Administration and other safety and health compliance needs.

Table 10.5. Resources by program
[$ in millions—BA;[a] personnel in full-time equivalents (FTEs)]

	Fiscal year							
	1990	1991	1992	1993	1994	1995	1996	1997
Office of Energy Research								
AT—Magnetic Fusion								
Operating expense	28.4	25.0	28.6	35.2	35.2	35.2	35.2	35.2
Capital equipment	1.5	1.0	1.7	2.9	2.9	2.9	2.9	2.9
Total program funding	**29.9**	**26.0**	**30.3**	**38.1**	**38.1**	**38.1**	**38.1**	**38.1**
Technical personnel	105.0	85.2	85.0	87.7	87.7	87.7	87.7	87.7
Other direct personnel	53.1	37.5	34.2	58.6	58.6	58.6	58.6	58.6
Total direct personnel	**158.1**	**122.7**	**119.2**	**146.3**	**146.3**	**146.3**	**146.3**	**146.3**
KA—High Energy Physics								
Operating expense	0.4	0.4	2.0	2.5	2.6	2.8	2.9	3.0
Technical personnel	1.9	3.2	6.3	7.4	7.8	8.2	8.6	9.0
Other direct personnel	0.6	0.5	0.5	0.5	0.5	0.6	0.6	0.6
Total direct personnel	**2.5**	**3.7**	**6.8**	**7.9**	**8.3**	**8.8**	**9.2**	**9.6**
KB—Nuclear Physics								
Operating expense	13.4	12.7	13.6	14.9	15.6	16.4	17.2	18.1
Capital equipment	1.7	1.0	0.7	2.1	2.2	2.3	2.4	2.6
Construction	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total program funding	**15.3**	**13.7**	**14.3**	**17.0**	**17.8**	**18.7**	**19.6**	**20.7**
Technical personnel	75.1	69.2	64.0	65.3	68.6	72.0	75.6	79.4
Other direct personnel	2.0	1.7	1.2	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**77.1**	**70.9**	**65.2**	**65.3**	**68.6**	**72.0**	**75.6**	**79.4**

Table 10.5 (continued)

	Fiscal year							
	1990	1991	1992	1993	1994	1995	1996	1997
KC—Basic Energy Sciences								
Operating expense	69.4	88.8	127.0	127.9	134.3	141.0	148.1	155.5
Capital equipment	6.6	6.5	13.1	14.5	15.2	15.9	16.6	17.4
Construction	1.3	2.8	0.0	0.0	0.0	0.0	0.0	0.0
Total program funding	**77.3**	**98.1**	**140.1**	**142.4**	**149.5**	**156.9**	**164.7**	**172.9**
Proposed construction[b]			3.8	42.1	5.0	29.5	29.0	18.0
Technical personnel	346.4	388.7	466.0	477.1	501.0	526.0	552.3	579.9
Other direct personnel	24.6	42.5	68.0	26.9	28.2	29.7	31.1	32.7
Total direct personnel	**371.0**	**431.2**	**534.0**	**504.0**	**529.2**	**555.7**	**583.4**	**612.6**
KD—Energy Research Analyses								
Operating expense	2.1	0.2	1.5	1.6	1.7	1.8	1.9	1.9
Technical personnel	4.8	2.8	2.5	2.5	2.6	2.8	2.9	3.0
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**4.8**	**2.8**	**2.5**	**2.5**	**2.6**	**2.8**	**2.9**	**3.0**
KG—Multiprogram Energy Laboratories—Facilities Support								
Operating expense	0.0	0.0	1.5	2.6	2.6	2.6	2.6	2.6
Construction[c]	16.9	6.5	0.0	0.0	0.0	0.0	0.0	0.0
Total program funding	**16.9**	**6.5**	**1.5**	**2.6**	**2.6**	**2.6**	**2.6**	**2.6**
Proposed construction	0.0		1.1	30.5	48.7	122.9	131.9	115.0
Technical personnel	0.0	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Other direct personnel	0.0	5.2	3.4	7.5	7.5	7.5	7.5	7.5
Total direct personnel	**0.0**	**5.7**	**3.9**	**8.0**	**8.0**	**8.0**	**8.0**	**8.0**

Table 10.5 (continued)

	Fiscal year							
	1990	1991	1992	1993	1994	1995	1996	1997
KP—Biological and Environmental Research								
Operating expense	26.5	27.0	33.7	35.9	35.9	35.9	35.9	35.9
Capital equipment	1.2	1.4	2.8	4.4	4.4	4.4	4.4	4.4
Total program funding	**27.7**	**28.4**	**36.5**	**40.3**	**40.3**	**40.3**	**40.3**	**40.3**
Proposed construction	0.0			20.0	47.0	47.0	8.0	0.0
Technical personnel	112.5	98.2	134.2	133.4	133.4	133.4	133.4	133.4
Other direct personnel	3.1	4.6	8.9	7.5	7.5	7.5	7.5	7.5
Total direct personnel	**115.6**	**102.8**	**143.1**	**140.9**	**140.9**	**140.9**	**140.9**	**140.9**
KS—Superconducting Super Collider								
Operating expense	0.5	0.8	0.8	0.6	0.6	0.7	0.7	0.7
Capital equipment	0.2	0.2	0.5	0.9	0.9	1.0	1.0	1.1
Total program funding	**0.7**	**1.0**	**1.3**	**1.5**	**1.5**	**1.7**	**1.7**	**1.8**
Technical personnel	1.6	2.2	3.3	3.0	3.2	3.3	3.5	3.6
Other direct personnel	0.0	0.2	1.1	0.2	0.2	0.2	0.2	0.2
Total direct personnel	**1.6**	**2.4**	**4.4**	**3.2**	**3.4**	**3.5**	**3.7**	**3.8**
KT—University and Science Education								
Operating expense	0.8	1.5	2.0	1.7	1.8	1.9	2.0	2.1
Technical personnel	4.1	4.0	3.3	2.8	2.9	3.0	3.2	3.4
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**4.1**	**4.0**	**3.3**	**2.8**	**2.9**	**3.0**	**3.2**	**3.4**

	Fiscal year							
	1990	1991	1992	1993	1994	1995	1996	1997
Landlord								
Operating expense	0.0	0.0	0.0	53.6[d]	53.6	53.6	53.6	53.6
General-purpose equipment	3.0	0.0	0.0	7.7	7.7	7.7	7.7	7.7
General plant projects construction	6.0	0.0	0.0	24.4	24.4	24.4	24.4	24.4
Total program	**9.0**	**0.0**	**0.0**	**85.7**	**85.7**	**85.7**	**85.7**	**85.7**
Technical personnel	0.0	0.0	0.0	122.5	122.5	122.5	122.5	122.5
Other direct personnel	0.0	0.0	0.0	27.0	27.0	27.0	27.0	27.0
Total direct personnel	**0.0**	**0.0**	**0.0**	**149.5**	**149.5**	**149.5**	**149.5**	**149.5**
Total Office of Energy Research								
Operating expense	141.5	156.4	210.7	276.5[d]	283.9	291.9	300.1	308.6
Capital equipment	14.2	10.1	18.8	32.5	33.3	34.2	35.0	36.1
Construction	24.4	9.3	0.0	24.4	24.4	24.4	24.4	24.4
Total program funding	**180.1**	**175.8**	**229.5**	**333.4**	**341.6**	**350.5**	**359.5**	**369.1**
Proposed construction	0.0	0.0	4.9	92.6	100.1	199.4	168.9	133.0
Technical personnel	651.4	654.0	763.9	902.2	930.2	959.4	990.2	1022.4
Other direct personnel	83.4	92.2	115.6	128.2	129.5	131.1	132.5	134.1
Total direct personnel	**734.8**	**746.2**	**879.5**	**1030.4[d]**	**1059.7**	**1090.5**	**1122.7**	**1156.5**
Assistant Secretary for Nuclear Energy								
AF—Nuclear Energy Research and Development								
Operating expense	31.5	30.4	37.1	32.9	32.9	32.9	32.9	32.9
Capital equipment	1.3	0.6	1.3	1.6	1.6	1.6	1.6	1.6
Total program funding	**32.8**	**31.0**	**38.4**	**34.5**	**34.5**	**34.5**	**34.5**	**34.5**
Technical personnel	127.5	138.6	152.0	133.8	133.8	133.8	133.8	133.8
Other direct personnel	15.1	21.9	20.7	10.9	10.9	10.9	10.9	10.9
Total direct personnel	**142.6**	**160.5**	**172.7**	**144.7**	**144.7**	**144.7**	**144.7**	**144.7**

Table 10.5 (continued)

	Fiscal year							
	1990	1991	1992	1993	1994	1995	1996	1997
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	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**0.3**	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**
CD—Uranium Enrichment								
Operating expense	0.7	0.6	0.4	0.4	0.4	0.4	0.4	0.4
Technical personnel	1.5	1.9	1.8	1.8	1.8	1.8	1.8	1.8
Other direct personnel	0.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**2.0**	**2.0**	**1.8**	**1.8**	**1.8**	**1.8**	**1.8**	**1.8**
KK—Policy and Management—Nuclear Energy								
Operating expense	0.0	2.2	1.2	1.5	1.5	1.5	1.5	1.5
Technical personnel	0.0	1.4	1.5	1.5	1.5	1.5	1.5	1.5
Other direct personnel	0.0	2.9	3.0	3.6	3.6	3.6	3.6	3.6
Total direct personnel	**0.0**	**4.3**	**4.5**	**5.1**	**5.1**	**5.1**	**5.1**	**5.1**
ST—Isotope Production and Distribution Program[e]								
Operating expense	14.7	3.1	13.5	16.1	16.9	17.8	18.7	19.6
Capital equipment	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1
Total program funding	**14.8**	**3.2**	**13.7**	**16.2**	**17.0**	**17.9**	**18.8**	**19.7**
Technical personnel	49.0	36.5	50.4	55.7	58.5	61.4	64.5	67.7
Other direct personnel	3.1	15.9	35.7	39.1	41.1	43.2	45.4	47.7
Total direct personnel	**52.1**	**52.4**	**86.1**	**94.8**	**99.6**	**104.6**	**109.9**	**115.4**

Table 10.5 (continued)

	Fiscal year							
	1990	1991	1992	1993	1994	1995	1996	1997
Total Assistant Secretary for Nuclear Energy								
Operating expense	46.9	36.3	52.3	51.0	51.8	52.7	53.6	54.5
Capital equipment	1.4	0.7	1.5	1.7	1.7	1.7	1.7	1.7
Total program funding	**48.3**	**37.0**	**53.8**	**52.7**	**53.5**	**54.4**	**55.3**	**56.2**
Technical personnel	178.3	178.8	206.1	193.2	196.0	198.9	202.0	205.2
Other direct personnel	18.7	40.8	59.4	53.6	55.6	57.7	59.9	62.2
Total direct personnel	**197.0**	**219.6**	**265.5**	**246.8**	**251.6**	**256.6**	**261.9**	**267.4**
Office of New Production Reactors								
NP—New Production Reactors[f]								
Operating expense	10.2	(0.7)[g]	0.0	0.0	0.0	0.0	0.0	0.0
Capital equipment	0	1.2	0.4	1.1	1.1	0.9	0.4	0.0
Construction	6.7	9.2	8.1	8.8	8.8	7.0	3.5	0.0
Total program funding	**16.9**	**9.7**	**8.5**	**9.9**	**9.9**	**7.9**	**3.9**	**0.0**
Proposed construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Technical personnel	59.2	1.1	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**60.9**	**1.1**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Total Office of New Production Reactors[f]								
Operating expense	10.2	(0.7)[g]	0.0	0.0	0.0	0.0	0.0	0.0
Capital equipment	0.0	1.2	0.4	1.1	1.1	0.9	0.4	0.0
Construction	6.7	9.2	8.1	8.8	8.8	7.0	3.5	0.0
Total program funding	**16.9**	**9.7**	**8.5**	**9.9**	**9.9**	**7.9**	**3.9**	**0.0**
Proposed construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Technical personnel	59.2	1.1	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**60.9**	**1.1**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

Table 10.5 (continued)

	Fiscal year							
	1990	1991	1992	1993	1994	1995	1996	1997
Office of Civilian Radioactive Waste Management								
DB—Nuclear Waste Fund								
Operating expense	7.1	8.7	11.4	11.9	12.2	12.7	13.4	13.9
Capital equipment	0.0	0.0	0.0	2.2	0.0	0.0	0.0	0.0
Total program funding	**7.1**	**8.7**	**11.4**	**14.1**	**12.2**	**12.7**	**13.4**	**13.9**
Technical personnel	14.3	11.4	17.2	17.8	18.0	18.2	18.4	18.6
Other direct personnel	2.0	4.0	4.7	4.6	4.6	4.6	4.7	4.7
Total direct personnel	**16.3**	**15.4**	**21.9**	**22.4**	**22.6**	**22.8**	**23.1**	**23.3**
Total Office of Civilian Radioactive Waste Management								
Operating expense	7.1	8.7	11.4	11.9	12.2	12.7	13.4	13.9
Capital equipment	0.0	0.0	0.0	2.2	0.0	0.0	0.0	0.0
Total program funding	**7.1**	**8.7**	**11.4**	**14.1**	**12.2**	**12.7**	**13.4**	**13.9**
Technical personnel	14.3	11.4	17.2	17.8	18.0	18.2	18.4	18.6
Other direct personnel	2.0	4.0	4.7	4.6	4.6	4.6	4.7	4.7
Total direct personnel	**16.3**	**15.4**	**21.9**	**22.4**	**22.6**	**22.8**	**23.1**	**23.3**
Assistant Secretary for Defense Programs								
GB—Weapons Activities								
Operating expense	1.9	0.2	0.4	0.5	0.5	0.5	0.5	0.5
Technical personnel	9.9	1.8	3.1	3.0	3.0	3.0	3.0	3.0
Other direct personnel	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**10.4**	**1.8**	**3.1**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**

Table 19.5—continued

	Fiscal year							
	1990	1991	1992	1993	1994	1995	1996	1997
GD—Nuclear Safeguards and Security								
Operating expense	0.5	0.5	0.6	0.6	0.6	0.6	0.6	0.6
Capital equipment	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total program funding	**0.7**	**0.6**	**0.7**	**0.7**	**0.7**	**0.7**	**0.7**	**0.7**
Technical personnel	3.3	2.9	3.3	3.3	3.3	3.3	3.3	3.3
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**3.3**	**2.9**	**3.3**	**3.3**	**3.3**	**3.3**	**3.3**	**3.3**
GE—Materials Production								
Operating expense	5.3	6.7	10.2	11.1	11.7	12.3	12.9	13.5
Capital equipment	0.2	0.3	1.7	1.9	2.0	2.1	2.2	2.3
Total program funding	**5.5**	**7.0**	**11.9**	**13.0**	**13.7**	**14.4**	**15.1**	**15.8**
Proposed construction	0.0	0.0	0.0	1.1	1.2	1.3	1.4	1.5
Technical personnel	29.2	36.1	54.1	48.8	51.2	53.8	56.5	59.3
Other direct personnel	1.7	1.1	2.7	2.4	2.5	2.6	2.7	2.8
Total direct personnel	**30.9**	**37.2**	**56.8**	**51.2**	**53.7**	**56.4**	**59.2**	**62.1**
Total Assistant Secretary for Defense Programs								
Operating expense	7.7	7.4	11.2	12.2	12.8	13.4	14.0	14.6
Capital equipment	0.4	0.4	1.8	2.0	2.1	2.2	2.3	2.4
Total program funding	**8.1**	**7.8**	**13.0**	**14.2**	**14.9**	**15.6**	**16.3**	**17.0**
Proposed construction	0.0	0.0	0.0	1.1	1.2	1.3	1.4	1.5
Technical personnel	42.4	40.8	60.5	55.1	57.5	60.1	62.8	65.6
Other direct personnel	2.2	1.1	2.7	2.4	2.5	2.6	2.7	2.8
Total direct personnel	**44.6**	**41.9**	**63.2**	**57.5**	**60.0**	**62.7**	**65.5**	**68.4**

Table 10.5 (continued)

	Fiscal year							
	1990	1991	1992	1993	1994	1995	1996	1997
Assistant Secretary for Conservation and Renewable Energy								
AK—Electric Energy Systems								
Operating expense	4.4	10.6	11.5	12.6	12.6	12.6	12.6	12.6
Capital equipment	0.0	0.3	0.5	1.0	1.0	1.0	1.0	1.0
Total program funding	**4.4**	**10.9**	**12.0**	**13.6**	**13.6**	**13.6**	**13.6**	**13.6**
Technical personnel	16.6	18.3	23.6	26.3	26.3	26.3	26.3	26.3
Other direct personnel	0.0	0.8	2.1	1.4	1.4	1.4	1.4	1.4
Total direct personnel	**16.6**	**19.1**	**25.7**	**27.7**	**27.7**	**27.7**	**27.7**	**27.7**
AL—Energy Storage Systems								
Operating expense	0.4	1.2	1.4	1.3	1.3	1.3	1.3	1.3
Technical personnel	1.7	1.5	2.5	1.7	1.7	1.7	1.7	1.7
Other direct personnel	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**1.8**	**1.5**	**2.5**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**
AM—Geothermal Energy								
Operating expense	0.0	0.5	1.4	0.5	0.4	0.4	0.4	0.4
Technical personnel	0.0	2.0	4.3	2.6	1.9	1.9	1.9	1.9
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**0.0**	**2.0**	**4.3**	**2.6**	**1.9**	**1.9**	**1.9**	**1.9**
CE—Hydropower								
Operating expense	0.2	0.2	0.7	1.3	1.3	1.3	1.3	1.3
Technical personnel	0.4	0.9	2.0	3.0	3.0	3.0	3.0	3.0
Other direct personnel	0.1	0.0	0.5	1.0	1.0	1.0	1.0	1.0
Total direct personnel	**0.5**	**0.9**	**2.5**	**4.0**	**4.0**	**4.0**	**4.0**	**4.0**

Table 10.5 (continued)

	Fiscal year							
	1990	1991	1992	1993	1994	1995	1996	1997
EB—Solar Energy								
Operating expense	3.3	4.5	10.6	10.6	10.6	10.6	10.6	10.6
Capital equipment	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1
Total program funding	**3.5**	**4.7**	**10.7**	**10.7**	**10.7**	**10.7**	**10.7**	**10.7**
Technical personnel	7.8	10.0	13.4	13.8	13.8	13.8	13.8	13.8
Other direct personnel	0.0	0.1	1.1	0.7	0.7	0.7	0.7	0.7
Total direct personnel	**7.8**	**10.1**	**14.5**	**14.5**	**14.5**	**14.5**	**14.5**	**14.5**
EC—Buildings and Community Systems								
Operating expense	9.3	12.3	15.1	19.6	19.6	19.6	19.6	19.6
Capital equipment	0.2	0.7	1.0	0.9	0.9	0.9	0.9	0.9
Total program funding	**9.5**	**13.0**	**16.1**	**20.5**	**20.5**	**20.5**	**20.5**	**20.5**
Technical personnel	32.7	29.0	36.0	44.6	44.6	44.6	44.6	44.6
Other direct personnel	0.0	1.8	2.5	0.3	0.3	0.3	0.3	0.3
Total direct personnel	**32.7**	**30.8**	**38.5**	**44.9**	**44.9**	**44.9**	**44.9**	**44.9**
ED—Industrial Energy Conservation								
Operating expense	2.0	1.9	3.7	4.2	4.2	4.2	4.2	4.2
Capital equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total program funding	**2.0**	**1.9**	**3.7**	**4.2**	**4.2**	**4.2**	**4.2**	**4.2**
Technical personnel	11.0	7.0	8.9	11.1	11.1	11.1	11.1	11.1
Other direct personnel	0.0	0.3	0.9	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**11.0**	**7.3**	**9.8**	**11.1**	**11.1**	**11.1**	**11.1**	**11.1**

Table 10.5 (continued)

	Fiscal year							
	1990	1991	1992	1993	1994	1995	1996	1997
EE—Transportation								
Operating expense	20.0	19.1	23.4	28.7	28.7	28.7	28.7	28.7
Capital equipment	1.4	1.7	2.7	1.9	1.9	1.9	1.9	1.9
Total program funding	**21.4**	**20.8**	**26.1**	**30.6**	**30.6**	**30.6**	**30.6**	**30.6**
Technical personnel	44.4	40.4	44.9	52.6	52.6	52.6	52.6	52.6
Other direct personnel	0.6	1.0	2.2	0.2	0.2	0.2	0.2	0.2
Total direct personnel	**45.0**	**41.4**	**47.1**	**52.8**	**52.8**	**52.8**	**52.8**	**52.8**
EF—State and Local Programs								
Operating expense	1.8	2.4	1.9	0.7	1.7	1.7	1.7	1.7
Technical personnel	3.7	4.6	3.6	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	**3.7**	**4.6**	**3.6**	**2.7**	**2.7**	**2.7**	**2.7**	**2.7**
EG—Multisector								
Operating expense	5.6	5.2	6.1	6.7	6.7	6.7	6.7	6.7
Capital equipment	0.5	0.7	0.9	0.8	0.8	0.8	0.8	0.8
Total program funding	**6.1**	**5.9**	**7.0**	**7.5**	**7.5**	**7.5**	**7.5**	**7.5**
Technical personnel	18.6	16.5	21.7	21.9	21.9	21.9	21.9	21.9
Other direct personnel	0.7	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**19.3**	**16.6**	**21.7**	**21.9**	**21.9**	**21.9**	**21.9**	**21.9**
Total Assistant Secretary for Conservation and Renewable Energy								
Operating expense	47.0	57.9	75.8	86.2	87.1	87.1	87.1	87.1
Capital equipment	2.3	3.6	5.2	4.7	4.7	4.7	4.7	4.7
Total program funding	**49.3**	**61.5**	**81.0**	**90.9**	**91.8**	**91.8**	**91.8**	**91.8**
Technical personnel	136.9	130.2	160.9	180.3	179.6	179.6	179.6	179.6
Other direct personnel	1.5	4.1	9.3	3.6	3.6	3.6	3.6	3.6
Total direct personnel	**138.4**	**134.3**	**170.2**	**183.9**	**183.2**	**183.2**	**183.2**	**183.2**

Table 10.5 (continued)

	Fiscal year							
	1990	1991	1992	1993	1994	1995	1996	1997
Assistant Secretary for Fossil Energy								
AA—Coal								
Operating expense	5.6	5.7	6.0	8.2	8.2	8.2	8.2	8.2
Capital equipment	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Total program funding	**5.6**	**5.8**	**6.1**	**8.2**	**8.2**	**8.2**	**8.2**	**8.2**
Technical personnel	15.7	14.3	14.9	16.0	16.0	16.0	16.0	16.0
Other direct personnel	0.1	0.3	0.2	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**15.8**	**14.6**	**15.1**	**16.0**	**16.0**	**16.0**	**16.0**	**16.0**
AC—Petroleum								
Operating expense	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Technical personnel	0.0	0.2	0.4	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**	**0.2**	**0.4**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
AZ—Innovative Clean Coal Technology								
Operating expense	0.5	0.5	0.8	0.9	0.9	0.9	0.9	0.9
Technical personnel	3.0	2.7	6.2	5.3	5.3	5.3	5.3	5.3
Other direct personnel	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**3.0**	**2.8**	**6.2**	**5.3**	**5.3**	**5.3**	**5.3**	**5.3**
CB—Naval Petroleum and Oil Shale Reserves								
Operating expense	*h*	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Technical personnel	0.2	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	**0.2**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

Table 10.5 (continued)

	Fiscal year							
	1990	1991	1992	1993	1994	1995	1996	1997
SA—Strategic Petroleum Reserve								
Operating expense	0.2	0.3	0.5	0.5	0.5	0.5	0.5	0.5
Technical personnel	1.7	1.7	2.1	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	**1.7**	**1.7**	**2.1**	**2.7**	**2.7**	**2.7**	**2.7**	**2.7**
Total Assistant Secretary for Fossil Energy								
Operating expense	6.3	6.6	7.4	9.6	9.6	9.6	9.6	9.6
Capital equipment	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Total program funding	**6.3**	**6.7**	**7.5**	**9.6**	**9.6**	**9.6**	**9.6**	**9.6**
Technical personnel	20.6	18.9	23.6	24.0	24.0	24.0	24.0	24.0
Other direct personnel	0.1	0.4	0.2	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**20.7**	**19.3**	**23.8**	**24.0**	**24.0**	**24.0**	**24.0**	**24.0**
Assistant Secretary for Environment, Safety, and Health								
HA—Environment Research and Development								
Operating expense	4.6	6.6	5.3	4.9	4.9	4.9	4.9	4.9
Capital equipment	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Total program funding	**4.6**	**6.6**	**5.4**	**5.0**	**5.0**	**5.0**	**5.0**	**5.0**
Proposed construction	0.0	0.0	0.0	0.0	0.0	1.5	6.5	0.0
Technical personnel	15.1	14.6	18.5	16.0	16.0	16.0	16.0	16.0
Other direct personnel	4.2	0.6	0.4	0.2	0.2	0.2	0.2	0.2
Total direct personnel	**19.3**	**15.2**	**18.9**	**16.2**	**16.2**	**16.2**	**16.2**	**16.2**
HR—Epidemiologic Activities								
Operating expense	0.0	0.2	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	0.0	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Total direct personnel	**0.0**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**

	Fiscal year							
	1990	1991	1992	1993	1994	1995	1996	1997
HS—Office of Security Evaluations								
Operating expense	0.0	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	0.0	0.5	0.4	0.4	0.4	0.4	0.4	0.4
Total direct personnel	**0.0**	**0.5**	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**
Total Assistant Secretary for Environment, Safety, and Health								
Operating expense	4.6	6.9	5.6	5.2	5.2	5.2	5.2	5.2
Capital equipment	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Total program funding	**4.6**	**6.9**	**5.7**	**5.3**	**5.3**	**5.3**	**5.3**	**5.3**
Proposed construction	0.0	0.0	0.0	0.0	0.0	1.5	6.5	0.0
Technical personnel	15.1	14.8	18.7	16.2	16.2	16.2	16.2	16.2
Other direct personnel	4.2	1.1	0.8	0.6	0.6	0.6	0.6	0.6
Total direct personnel	**19.3**	**15.9**	**19.5**	**16.8**	**16.8**	**16.8**	**16.8**	**16.8**
Energy Information Administration								
TA—Energy Information Administration System								
Operating expense	1.0	1.0	1.3	1.4	1.4	1.4	1.4	1.4
Technical personnel	2.1	2.5	3.0	3.3	3.3	3.3	3.3	3.3
Other direct personnel	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**2.2**	**2.5**	**3.0**	**3.3**	**3.3**	**3.3**	**3.3**	**3.3**
Total Energy Information Administration								
Operating expense	1.0	1.0	1.3	1.4	1.4	1.4	1.4	1.4
Technical personnel	2.1	2.5	3.0	3.3	3.3	3.3	3.3	3.3
Other direct personnel	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**2.2**	**2.5**	**3.0**	**3.3**	**3.3**	**3.3**	**3.3**	**3.3**

Table 10.5 (continued)

	Fiscal year							
	1990	1991	1992	1993	1994	1995	1996	1997
Office of Administration and Human Resource Management								
WB—In-House Energy Management								
Operating expense	0.1	0.4	0.2	0.2	0.2	0.2	0.2	0.2
Construction	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total program funding	**0.9**	**0.4**	**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	0.8	0.9	0.3	0.3	0.3	0.3	0.3	0.3
Total direct personnel	**0.8**	**0.9**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**
Total Office of Administration and Human Resource Management								
Operating expense	0.1	0.4	0.2	0.2	0.2	0.2	0.2	0.2
Construction	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total program funding	**0.9**	**0.4**	**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	0.8	0.9	0.3	0.3	0.3	0.3	0.3	0.3
Total direct personnel	**0.8**	**0.9**	**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	1.2	2.1	3.0	2.5	2.5	2.5	2.5	2.5
Technical personnel	2.5	6.8	11.6	9.1	9.1	9.1	9.1	9.1
Other direct personnel	0.0	0.4	0.4	0.1	0.1	0.1	0.1	0.1
Total direct personnel	**2.5**	**7.2**	**12.0**	**9.2**	**9.2**	**9.2**	**9.2**	**9.2**
Total Office of Policy, Planning, and Analysis								
Operating expense	1.2	2.1	3.0	2.5	2.5	2.5	2.5	2.5
Technical personnel	2.5	6.8	11.6	9.1	9.1	9.1	9.1	9.1
Other direct personnel	0.0	0.4	0.4	0.1	0.1	0.1	0.1	0.1
Total direct personnel	**2.5**	**7.2**	**12.0**	**9.2**	**9.2**	**9.2**	**9.2**	**9.2**

Table 10.5 (continued)

	Fiscal year							
	1990	1991	1992	1993	1994	1995	1996	1997
Federal Energy Regulatory Commission								
VR—Federal Energy Regulatory Commission								
Operating expense	0.0	0.6	2.5	2.5	2.5	2.5	2.5	2.5
Technical personnel	0.3	2.8	17.0	16.0	16.0	16.0	16.0	16.0
Other direct personnel	0.0	0.0	0.2	0.2	0.2	0.2	0.2	0.2
Total direct personnel	**0.3**	**2.8**	**17.2**	**16.2**	**16.2**	**16.2**	**16.2**	**16.2**
Total Federal Energy Regulatory Commission								
Operating expense	0.0	0.6	2.5	2.5	2.5	2.5	2.5	2.5
Technical personnel	0.3	2.8	17.0	16.0	16.0	16.0	16.0	16.0
Other direct personnel	0.0	0.0	0.2	0.2	0.2	0.2	0.2	0.2
Total direct personnel	**0.3**	**2.8**	**17.2**	**16.2**	**16.2**	**16.2**	**16.2**	**16.2**
Assistant Secretary for International Affairs and Energy Emergencies								
NB—Emergency Preparedness								
Operating expense	0.1	0.0	0.2	0.2	0.2	0.2	0.2	0.2
Technical personnel	0.1	0.4	0.8	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	**0.1**	**0.4**	**0.8**	**0.9**	**0.9**	**0.9**	**0.9**	**0.9**
Total Assistant Secretary for International Affairs and Energy Emergencies								
Operating expense	0.1	0.0	0.2	0.2	0.2	0.2	0.2	0.2
Technical personnel	0.1	0.4	0.8	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	**0.1**	**0.4**	**0.8**	**0.9**	**0.9**	**0.9**	**0.9**	**0.9**

Table 10.5 (continued)

	Fiscal year							
	1990	1991	1992	1993	1994	1995	1996	1997
Office of Environmental Restoration and Waste Management								
EW—Environmental Restoration and Waste Management—Defense								
Operating expense	30.4	7.7	11.3	18.7	0.0	0.0	0.0	0.0
Capital equipment	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total program funding	**33.9**	**7.7**	**11.3**	**18.7**	**0.0**	**0.0**	**0.0**	**0.0**
Technical personnel	65.8	25.4	25.6	48.2	0.0	0.0	0.0	0.0
Other direct personnel	16.3	1.0	0.6	6.6	0.0	0.0	0.0	0.0
Total direct personnel	**82.1**	**26.4**	**26.2**	**54.8**	**0.0**	**0.0**	**0.0**	**0.0**
EX—Environmental Restoration and Waste Management—Nondefense								
Operating expense	19.4	5.2	0.2	0.1	0.0	0.0	0.0	0.0
Capital equipment	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total program funding	**19.9**	**5.2**	**0.2**	**0.1**	**0.0**	**0.0**	**0.0**	**0.0**
Technical personnel	66.0	3.3	1.3	0.2	0.0	0.0	0.0	0.0
Other direct personnel	3.0	0.7	0.3	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**69.0**	**4.0**	**1.6**	**0.2**	**0.0**	**0.0**	**0.0**	**0.0**
Landlord								
Operating expense	0.0	0.0	46.7[d]	0.0	0.0	0.0	0.0	0.0
General-purpose equipment	0.0	3.1	13.1	0.0	0.0	0.0	0.0	0.0
General plant projects construction	0.0	6.1	6.4	0.0	0.0	0.0	0.0	0.0
Total program funding	**0.0**	**9.2**	**66.2[d]**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Proposed general plant projects construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Technical personnel	0.0	13.9	121.8	0.0	0.0	0.0	0.0	0.0
Other direct personnel	0.0	3.3	21.8	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**0.0**	**17.2**	**143.6[d]**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

	Fiscal year							
	1990	1991	1992	1993	1994	1995	1996	1997
Total Office of Environmental Restoration and Waste Management								
Operating expense	49.8	12.9	58.2[d]	18.8	0.0	0.0	0.0	0.0
Capital equipment	1.3	3.1	13.1	0.0	0.0	0.0	0.0	0.0
Construction	2.7	6.1	6.4	0.0	0.0	0.0	0.0	0.0
Total program funding	**53.8**	**22.1**	**77.7[d]**	**18.8**	**0.0**	**0.0**	**0.0**	**0.0**
Proposed construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Technical personnel	131.8	42.6	148.7	48.4	0.0	0.0	0.0	0.0
Other direct personnel	19.3	5.0	22.7	6.6	0.0	0.0	0.0	0.0
Total direct personnel	**151.1**	**47.6**	**171.4[d]**	**55.0**	**0.0**	**0.0**	**0.0**	**0.0**
DOE Funding from Energy Systems Central Organizations								
CD—Uranium Enrichment								
Operating expense	7.8	3.1	0.0	0.0	0.0	0.0	0.0	0.0
Technical personnel	13.7	9.2	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	11.5	4.0	0.8	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**25.2**	**13.2**	**0.8**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
EW—Environmental Restoration and Waste Management—Defense								
Operating expense	0.0	29.9	66.1	117.7	117.7	117.7	117.7	117.7
Proposed construction	0.0	0.0	4.5	15.9	51.5	98.1	156.0	61.0
Technical personnel	0.0	177.0	228.8	356.7	356.7	356.7	356.7	356.7
Other direct personnel	0.0	24.7	55.0	109.7	109.7	109.7	109.7	109.7
Total direct personnel	**0.0**	**201.7**	**283.8**	**466.4**	**466.4**	**466.4**	**466.4**	**466.4**

Table 10.5 (continued)

	Fiscal year							
	1990	1991	1992	1993	1994	1995	1996	1997
EX—Environmental Restoration and Waste Management—Nondefense								
Operating expense	0.0	15.1	18.4	28.7	28.7	28.7	28.7	28.7
Construction	0.0	7.9	0.0	0.0	0.0	0.0	0.0	0.0
Total program funding	**0.0**	**23.0**	**18.4**	**28.7**	**28.7**	**28.7**	**28.7**	**28.7**
Proposed construction	0.0	0.0	0.1	0.0	3.0	10.0	7.0	11.1
Technical personnel	0.0	81.8	79.7	123.7	123.7	123.7	123.7	123.7
Other direct personnel	0.0	7.8	13.8	19.5	19.5	19.5	19.5	19.5
Total direct personnel	**0.0**	**89.6**	**93.5**	**143.2**	**143.2**	**143.2**	**143.2**	**143.2**
Total DOE Funding from Energy Systems Central Organizations								
Operating expense	7.8	48.1	84.5	146.4	146.4	146.4	146.4	146.4
Construction	0.0	7.9	0.0	0.0	0.0	0.0	0.0	0.0
Total program funding	**7.8**	**56.0**	**84.5**	**146.4**	**146.4**	**146.4**	**146.4**	**146.4**
Proposed construction	0.0	0.0	4.6	15.9	54.5	108.1	163.0	72.1
Technical personnel	13.7	268.0	308.5	480.4	480.4	480.4	480.4	480.4
Other direct personnel	11.5	36.5	69.6	129.2	129.2	129.2	129.2	129.2
Total direct personnel	**25.2**	**304.5**	**378.1**	**609.6**	**609.6**	**609.6**	**609.6**	**609.6**
Subtotal—DOE Programs								
Operating expense	331.3	344.6	524.3	624.6	615.8	625.8	636.2	646.7
Capital equipment	19.6	16.1	27.9	44.3	43.0	43.8	44.2	45.0
Construction	34.6	32.5	14.5	33.2	33.2	31.4	27.9	24.4
Total program funding	**385.5**	**393.2**	**566.7**	**702.1**	**692.0**	**701.0**	**708.3**	**716.1**
Proposed construction	0.0	0.0	9.5	109.6	156.4	310.3	339.8	206.6
Technical personnel	1268.7	1373.1	1740.5	1946.9	1931.2	1966.1	2002.9	2041.3
Other direct personnel	145.5	186.5	285.9	329.4	326.2	330.0	333.8	337.8
Total direct personnel	**1414.2**	**1559.6**	**2026.4**	**2276.3**	**2257.4**	**2296.1**	**2336.7**	**2379.1**

Table 3.0.5 (continued)

	Fiscal year							
	1990	1991	1992	1993	1994	1995	1996	1997
DOE Contractors and Operations Office								
Operating expense	32.9	24.6	28.9	31.5	31.5	31.5	31.5	31.5
Capital equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total program funding	**32.9**	**24.6**	**28.9**	**31.5**	**31.5**	**31.5**	**31.5**	**31.5**
Technical personnel	146.0	191.0	178.3	171.7	171.7	171.7	171.7	171.7
Other direct personnel	23.8	24.9	31.7	39.7	39.7	39.7	39.7	39.7
Total direct personnel	**169.8**	**215.9**	**210.0**	**211.4**	**211.4**	**211.4**	**211.4**	**211.4**
Total DOE Programs								
Operating expense	364.2	369.2	553.2[d]	656.1[d]	647.3	657.3	667.7	678.2
Capital equipment	19.6	16.1	27.9	44.3	43.0	43.8	44.2	45.0
Construction	34.6	32.5	14.5	33.2	33.2	31.4	27.9	24.4
Total program funding	**418.4**	**417.8**	**595.6[d]**	**733.6[d]**	**723.5**	**732.5**	**739.8**	**747.6**
Proposed construction	0.0	0.0	9.5	109.6	156.4	310.3	339.8	206.6
Technical personnel	1414.7	1564.1	1918.8	2118.6	2102.9	2137.8	2174.6	2213.0
Other direct personnel	169.3	211.4	317.6	369.1	365.9	369.7	373.5	377.5
Total direct personnel	**1584.0**	**1775.5**	**2236.4[d]**	**2487.7[d]**	**2468.8**	**2507.5**	**2548.1**	**2590.5**
Work for Others								
Nuclear Regulatory Commission								
Operating expense	17.2	15.1	18.0	16.9	16.9	16.9	16.9	16.9
Technical personnel	55.5	64.7	62.3	54.6	54.6	54.6	54.6	54.6
Other direct personnel	11.7	17.7	16.7	16.3	16.3	16.3	16.3	16.3
Total direct personnel	**67.2**	**82.4**	**79.0**	**70.9**	**70.9**	**70.9**	**70.9**	**70.9**
Department of Defense								
Operating expense	45.8	40.6	58.5	65.8	65.8	65.8	65.8	65.8
Technical personnel	165.4	190.4	198.7	215.6	215.6	215.6	215.6	215.6
Other direct personnel	17.6	21.3	11.1	5.0	5.0	5.0	5.0	5.0
Total direct personnel	**183.0**	**211.7**	**209.8**	**220.6**	**220.6**	**220.6**	**220.6**	**220.6**

Table 10.5 (continued)

	Fiscal year							
	1990	1991	1992	1993	1994	1995	1996	1997
National Aeronautics and Space Administration								
Operating expense	1.9	5.7	7.8	7.0	7.0	7.0	7.0	7.0
Technical personnel	5.9	23.1	22.7	16.5	16.5	16.5	16.5	16.5
Other direct personnel	0.4	9.5	11.8	14.2	14.2	14.2	14.2	14.2
Total direct personnel	**6.3**	**32.6**	**34.5**	**30.7**	**30.7**	**30.7**	**30.7**	**30.7**
Department of Health and Human Services								
Operating expense	4.8	3.7	5.3	5.5	5.5	5.5	5.5	5.5
Technical personnel	26.7	21.4	20.8	20.8	20.8	20.8	20.8	20.8
Other direct personnel	0.4	0.3	1.1	1.1	1.1	1.1	1.1	1.1
Total direct personnel	**27.1**	**21.7**	**21.9**	**21.9**	**21.9**	**21.9**	**21.9**	**21.9**
Environmental Protection Agency								
Operating expense	3.8	1.6	3.1	3.1	3.1	3.1	3.1	3.1
Technical personnel	20.3	13.2	15.2	14.8	14.8	14.8	14.8	14.8
Other direct personnel	2.1	0.1	1.5	1.5	1.5	1.5	1.5	1.5
Total direct personnel	**22.4**	**13.3**	**16.7**	**16.3**	**16.3**	**16.3**	**16.3**	**16.3**
National Science Foundation								
Operating expense	1.0	1.1	1.1	0.8	0.8	0.8	0.8	0.8
Technical personnel	2.2	1.4	2.3	2.5	2.5	2.5	2.5	2.5
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**2.2**	**1.4**	**2.3**	**2.5**	**2.5**	**2.5**	**2.5**	**2.5**
Federal Emergency Management Agency								
Operating expense	2.2	1.8	2.2	2.4	2.4	2.4	2.4	2.4
Technical personnel	2.6	5.3	4.4	4.8	4.8	4.8	4.8	4.8
Other direct personnel	1.1	1.6	1.7	1.7	1.7	1.7	1.7	1.7
Total direct personnel	**3.7**	**6.9**	**6.1**	**6.5**	**6.5**	**6.5**	**6.5**	**6.5**

Table 36.5 (continued)

	Fiscal year							
	1990	1991	1992	1993	1994	1995	1996	1997
Agency for International Development								
Operating expense	1.3	1.5	2.0	2.3	2.0	2.0	2.0	2.0
Technical personnel	4.4	2.8	3.2	3.1	8.0	8.0	8.0	8.0
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	**4.4**	**2.8**	**3.2**	**3.1**	**8.0**	**8.0**	**8.0**	**8.0**
Other Federal Agencies								
Operating expense	3.3	6.3	6.3	6.9	7.0	7.1	7.2	7.3
Technical personnel	26.7	25.7	23.4	25.6	19.0	19.4	19.8	20.2
Other direct personnel	1.3	0.9	1.9	1.7	1.7	1.7	1.7	1.7
Total direct personnel	**28.0**	**26.2**	**25.3**	**27.3**	**20.7**	**21.1**	**21.5**	**21.9**
Electric Power Research Institute								
Operating expense	2.9	2.2	1.9	0.7	0.7	0.7	0.7	0.7
Technical personnel	7.3	9.7	7.9	6.9	3.0	3.0	3.0	3.0
Other direct personnel	0.5	0.8	0.7	0.4	0.2	0.2	0.2	0.2
Total direct personnel	**7.8**	**10.5**	**8.6**	**7.3**	**3.2**	**3.2**	**3.2**	**3.2**
Other Nonfederal Agencies								
Operating expense	3.0	9.3	4.4	4.7	4.7	4.7	4.7	4.7
Technical personnel	14.2	25.4	14.1	15.0	15.0	15.0	15.0	15.0
Other direct personnel	0.8	0.6	0.3	0.2	0.4	0.4	0.4	0.4
Total direct personnel	**15.0**	**26.0**	**14.4**	**11.3**	**15.4**	**15.4**	**15.4**	**15.4**
Total Work for Others[i]								
Operating expense	87.2	88.9	110.6	116.1	115.9	116.0	116.1	116.2
Technical personnel	331.2	383.1	375.0	376.3	374.6	375.0	375.4	375.8
Other direct personnel	35.9	52.8	46.8	42.1	42.1	42.1	42.1	42.1
Total direct personnel	**367.1**	**435.9**	**421.8**	**418.4**	**416.7**	**417.1**	**417.5**	**417.9**

Table 10.5 (continued)

	Fiscal year							
	1990	1991	1992	1993	1994	1995	1996	1997
Total Program Resources								
Operating expense	451.4	458.1	663.8[d]	772.2[d]	763.2	773.3	783.8	794.4
Capital equipment	19.6	16.1	27.9	44.3	43.0	43.8	44.2	45.0
Construction	34.6	32.5	14.5	33.2	33.2	31.4	27.9	24.4
Total program funding	**505.6**	**506.7**	**706.2[d]**	**849.7[d]**	**839.4**	**848.5**	**855.9**	**863.8**
Proposed construction	0.0	0.0	9.5	109.6	156.4	310.3	339.8	206.6
Technical personnel	1745.9	1947.2	2293.8	2494.9	2477.5	2512.8	2550.0	2588.8
Other direct personnel	205.2	264.2	364.4	411.2	408.0	411.8	415.6	419.6
Total direct personnel	**1951.1**	**2211.4**	**2658.2[d]**	**2906.1[d]**	**2885.5**	**2924.6**	**2965.6**	**3008.4**

[a]Inflation escalation factor for FY 1992 and FY 1993 is 4.5%. Figures for FY 1994 through FY 1997 are in constant FY 1993 dollars. BA in tables is new BA requirements as requested in the FY 1993 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]Does not include total Advanced Neutron Source construction, which is to be determined.

[c]Includes general-purpose equipment (GPE) or general plant projects (GPP) funding from KG Program.

[d]Data include several field-work proposal proposed in 1992 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]Parentheses contain negative amounts, indicating a budgetary deficit.

[h]Less than $0.1 million or less than 0.1 FTE.

[i]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 (~$5.3 million in FY 1990) is reported through the Y-12 and K-25 financial plans.

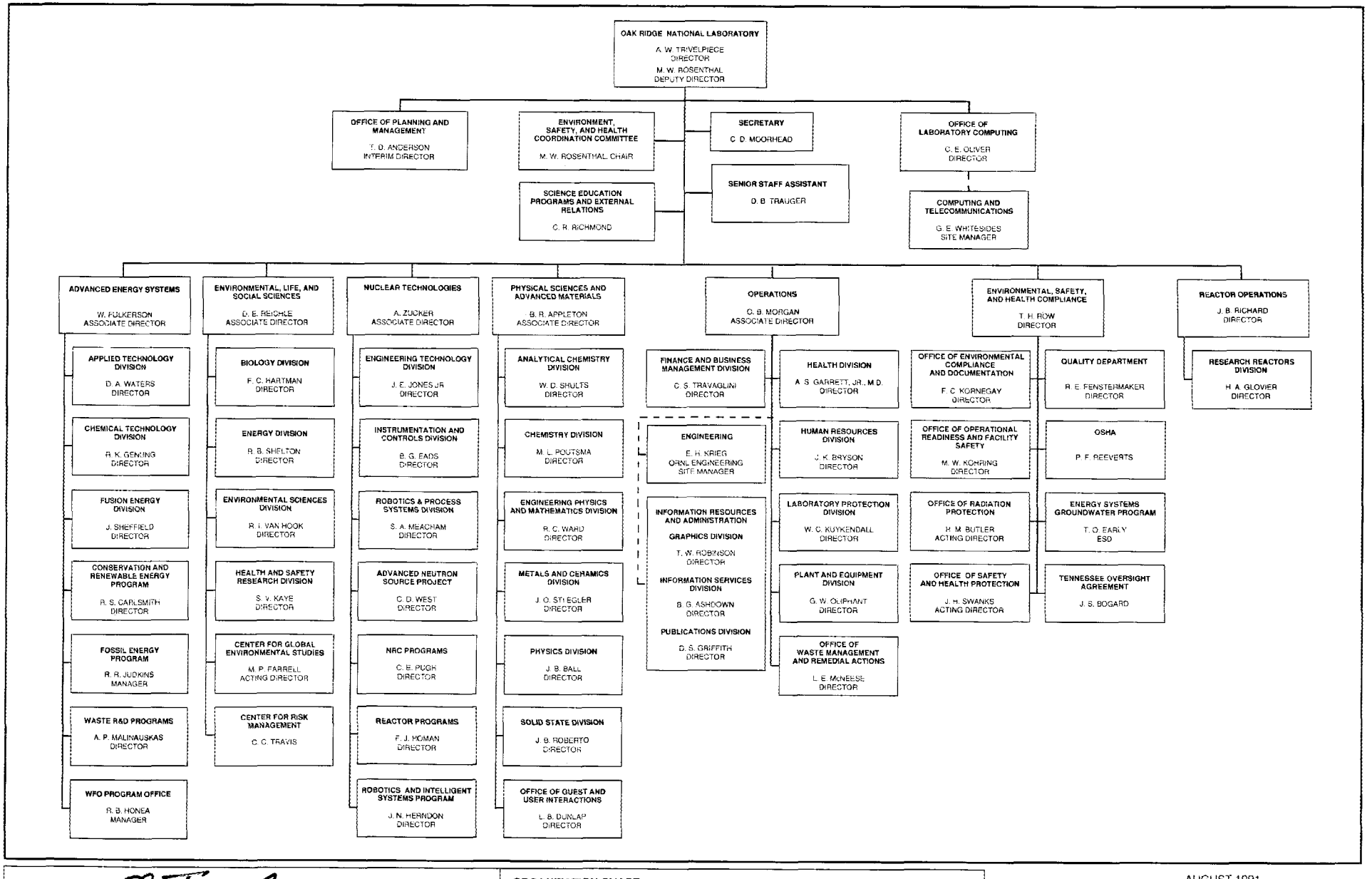
Table 10.6. Laboratory funding summary of environmental safety and health activities ($ in millions—BA)[a]

	Fiscal year		
	1991	1992	1993
Operating expense	72.4	118.0	148.0
Capital equipment	0.4	3.0	1.4
General plant projects	0.5	3.2	7.3
Line item	7.8	2.8	24.0
Total Laboratory	**81.1**	**127.0**	**180.7**

[a]Inflation escalation factor for FY 1992 and FY 1993 is 4.5%. BA in table is new BA requirement as requested in the FY 1993 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.

appendix

REPORTS TO PRESIDENT



APPROVED A. W. Trivelpiece

ORGANIZATION CHART:

OAK RIDGE NATIONAL LABORATORY

MARTIN MARIETTA ENERGY SYSTEMS, INC.

EFFECTIVE DATE AUGUST 1991

MARTIN MARIETTA

Abbreviations

AA	affirmative action
ACL	Advanced Computing Laboratory
ACRD	Atmospheric and Climate Research Division
ADANS	Airlift Deployment Analysis System
AEOD	Office for Analysis and Evaluation of Operational Data
AEPL	Advanced Environmental Photonics Laboratory
AFEAS	Alternative Fluorocarbons Environmental Acceptability Study
AFESC	Air Force Engineering Services Center
AGMEF	Ana G. Méndez Educational Foundation
AI	artificial intelligence
AIC	Advanced Industrial Concepts
AID	Agency for International Development
AIM	Accelerator Improvement and Maintenance
ALERT	Associated Laboratories for Excellence in Radiation Technology
ANL	Argonne National Laboratory
ANS	Advanced Neutron Source
API	American Petroleum Institute
AR&TD	Advanced Research and Technology Development
ARIES	Advanced Reactor Innovation and Evaluation Study
ARM	atmospheric radiation measurement
ATD	Applied Technology Division
ATF	Advanced Toroidal Facility
ATR	Advanced Test Reactor
ATSDR	Agency for Toxic Substances and Disease Registry
B&R	budget and reporting
B&W	Babcock and Wilcox
BA	budget authorization
BES	Basic Energy Sciences
BNL	Brookhaven National Laboratory
BOP	balance of plant
BPX	Burning Plasma Experiment
BRF	Bioprocessing Research Facility
BRL	Ballistic Research Laboratory
BSR	Bulk Shielding Reactor
BTESM	Building Thermal Envelope Systems and Materials
BWR	boiling water reactor
C&TD	Computing and Telecommunications Division
CCP	Clean Coal Program
CCS	Center for Computational Science

CDIAC	Carbon Dioxide Information Analysis Center
CDIARP	Carbon Dioxide Information Analysis and Research Program
CEF	Critical Experiments Facility
CEPO	Classroom Experimental Projects Office
CEQ	Council for Environmental Quality
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
CETI	Center for Educational Technology Innovation
CFC	chlorinated fluorocarbon or chlorofluorocarbon
CFRP	Consolidated Fuel Reprocessing Program
CH	contact-handled
CHAMMP	Computer Hardware, Advanced Mathematics, and Model Physics
CIT	Compact Ignition Tokamak
CORECT	Committee on Renewable Energy Commerce and Trade
CRADA	cooperative research and development agreement
CRESO	Clinch River Environmental Studies Organization
CSAM	Center for Study of Advanced Materials
CURE	chemical unit record estimates
CVI	chemical-vapor infiltration
D&D	decontamination and decommissioning
D&T	development and technology
DARPA	Defense Advanced Research Projects Agency
DC	direct cycle
DHHS	U.S. Department of Health and Human Services
DIMS	Data and Information Management System
DNA	deoxyribonucleic acid
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOE-BES	U.S. Department of Energy, Basic Energy Sciences
DOE-ER	U.S. Department of Energy, Energy Research
DOE-ID	U.S. Department of Energy, Idaho Falls Field Office
DOE-NP	U.S. Department of Energy, New Production Reactors
DOE-OR	U.S. Department of Energy, Oak Ridge Field Office
DOE-SR	U.S. Department of Energy, Savannah River Field Office
DOT	U.S. Department of Transportation
DP	Defense Programs
DSRD	Data Systems Research and Development
DTRC	David W. Taylor Naval Ship R&D Center ECA energy conversion area
ECH	electron-cyclotron heating
ECR	electron-cyclotron resonance
ECUT	Energy Conversion and Utilization Technologies
EDA	engineering design activities
EDP	engineering development plan
EGF	epidermal growth factor
EIA	Energy Information Administration

EIS	environmental impact statement
EMIC	Environmental Mutagen Information Center
EMP	electromagnetic pulse
EPA	U.S. Environmental Protection Agency
EPMD	Engineering Physics and Mathematics Division
EPRI	Electric Power Research Institute
EPSSC	Environmental and Physical Science Study Center
ER	environmental restoration
ES&H	environmental, safety, and health
ES&HC	environmental, safety, and health compliance
ESC	Ecological Study Center
ESD	Environmental Sciences Division
ETI	Education Technology Institute
ETP	Exploration Technology Program
FAA	Federal Aviation Administration
FARS	Future Armor Rearm System
FDA	U.S. Food and Drug Administration
FDDI	fiber-distributed data interface
FEDC	Fusion Engineering Design Center
FEMA	Federal Emergency Management Agency
FFA	federal facility agreement
FHWA	Federal Highway Administration
FIS	fluoroimmunosensor
FTE	full-time equivalent
FTIR	Fourier transform infrared
FUSRAP	Formerly Utilized Sites Remedial Action Project
FWP	field-work proposal
GCM	general circulation model
GDR	giant dipole resonance
GEIS	generic environmental impact statement
GLCA/ACM	Great Lakes Colleges Association/Associated Colleges of the Midwest
GPE	general-purpose equipment
GPP	general plant project
GSF	gross square feet
GT	gas turbine
HASRD	Health and Safety Research Division
HAZWRAP	Hazardous Waste Remedial Action Program
HBCU	historically black colleges and universities
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
HISTRAP	Heavy-Ion Storage Ring for Atomic Physics
HLW	high-level waste
HPC	high-performance computing
HPCC	High-Performance Computing and Communication
HPRR	Health Physics Research Reactor
HSST	Heavy Section Steel Technology

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
ICH	ion-cyclotron heating
ICM	interim corrective measure
ICRP	International Commission on Radiological Protection
INEL	Idaho National Engineering Laboratory
IPM	(p-iodophenyl) maleimide
IRA	Information Resources and Administration
IRML	Isotopes Research Materials Laboratory
IRP	Installation Restoration Program
ITER	International Thermonuclear Experimental Reactor
IVHS	intelligent vehicle and highway systems
JASPER	Japanese/American Shielding Program of Experimental Research
JET	Joint European Torus
LABCOM	U.S. Army Laboratory Command
LANL	Los Alamos National Laboratory
LBL	Lawrence Berkeley Laboratory
LET	linear-energy transfer
LLNL	Lawrence Livermore National Laboratory
LLW	low-level waste
LMR	liquid metal reactor
LTM	Laboratory Telerobotic Manipulator
LWR	light-water reactor
M&O	management and operating
MAC	Military Airlift Command
MAPTIC	Manufacturing and Processing Technology Integration Center
MEI	minority education institution
METC	Morgantown Energy Technology Center
MGPF	multiprogram general-purpose facility
MHTGR	modular high-temperature gas-cooled reactor
MIRT	minority institution research travel
MOU	memorandum of understanding
MS/MS	mass spectrometry/mass spectrometry
MS&E	Materials Science and Engineering
MSC	Military Sealift Command
MSDS	Material Safety Data Sheet
MSI	multisensor integration
MTMC	Military Traffic Management Command
NASA	National Aeronautics and Space Administration
NCA&TSU	North Carolina A&T State University
NCHGR	National Center for Human Genome Research
NCI	National Cancer Institute
NEESA	Navy Energy and Environmental Support Activity
NEP	nuclear electric propulsion
NEPA	National Environmental Policy Act

NERC	NEPA Environmental Review and Compliance
NERP	National Environmental Research Park
NES	National Energy Strategy
NG	newly generated
NGB	National Guard Bureau
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/Neutron Scattering Facility
NTP	nuclear thermal propulsion
NUSC	Navy Underwater Systems Center
NWC	nuclear weapons complex
OCRWM	Office of Civilian Radioactive Waste Management
OEA	Office of Environmental Analysis
OECD	Office of Environmental Compliance and Documentation
OGUI	Office of Guest and User Interactions
OHEA	EPA's Office of Health and Environmental Assessment
OHER	Office of Health and Environmental Research
ORA	Office of Risk Analysis
ORAU	Oak Ridge Associated Universities
ORDC	Oak Ridge Detector Center
ORELA	Oak Ridge Electron Linear Accelerator
ORGSBS	Oak Ridge Graduate School of Biomedical Sciences
ORIC	Oak Ridge Isosynchronous Cyclotron
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Research Reactor
OSHA	Occupational Safety and Health Administration
OTD	Office of Technology Development
OTT	Office of Technology Transfer
OWMRA	Office of Waste Management and Remedial Action
P&E	Plant and Equipment
PC	personal computer
PCB	polychlorinated biphenyl
PICS	Partners in Computational Science
PI	Performance Indicator Program
PNA	polynuclear aromatic (hydrocarbons)
PNC	Power Reactor and Nuclear Fuel Development Corporation (Japan)
PNL	Pacific Northwest Laboratories
QA	quality assurance
QAS	quality assurance specialist
R&D	research and development

Radiation Calibration Facility
Remedial Action Program
Remedial Action Program Information Center
Resource Conservation and Recovery Act
Radiochemical Engineering Development Center
Office of Nuclear Regulatory Research
Recycle Equipment Test Facility
radio frequency
Radio Frequency Test Facility
remote handled
Relativistic Heavy-Ion Collider
remedial investigation
Robotics and Intelligent Systems Program
Research Materials Collection
Radiochemical Processing Plant
Radiation Shielding Information Center
radioisotope thermoelectric generator
surveillance and maintenance
Saturday Academy of Computing and Mathematics
Southern Association of High-Energy Physics
Service Academies Research Associates
steam cycle
Sequence Coding and Search System
Solenoidal Detector Collaboration
Strategic Defense Initiative
Space and Defense Technology Program
Summer Educational Experience for the Disadvantaged
Space Exploration Initiative
Science Education Programs and External Relations
Science and Engineering Research Semester
Surplus Facilities Management Project
Super Fixed Target
Surface Modification and Characterization/Collaborative Research Center
Science and Mathematics Action for Revitalized Teachers
Space Nuclear Auxiliary Power
Superconductivity Pilot Center
Strategic Petroleum Reserve
Savannah River Laboratory
Superconducting Super Collider
Summer Teachers as Resources
Superconducting Technology for Electric Power Systems
Science Teachers' Research for Vital Involvement
Southeastern University Research Association
solid waste storage area
technology applications bulletin
Tank Automotive Command
trichloroethylene
Tennessee Department of Environment and Conservation

TDHF	time-dependent Hartree-Fock
TDP	technology development plan
TECOM	Test and Evaluation Command
TEXTOR	Tokamak Experiment for Technically Oriented Research
TFTR	Tokamak Fusion Test Reactor
TIRC	Toxicology Information Response Center
TOPO	Transportation Operations Project Office
TPP	Transuranium Processing Plant
TQM	Total Quality Management
TRA	Teacher Research Associates
TRU	transuranic
TSD	treatment, storage, and disposal
TSR	Tower Shielding Reactor
TVA	Tennessee Valley Authority
UE	Uranium Enrichment
UHV	ultrahigh vacuum
ULCP	University Laboratory Cooperative Program
UMTRAP	Uranium Mill Tailings Remedial Action Project
UPR	University of Puerto Rico
USDA	U.S. Department of Agriculture
USEP	University and Science Education Programs
U.S.S.R.	Union of Soviet Socialist Republics
UST	underground storage tank
USTRANSCOM	United States Transportation Command
UT	University of Tennessee
UTK	The University of Tennessee, Knoxville
UV	ultraviolet
UV-B	ultraviolet-B
VMT	vehicle-miles-of-travel
WAG	waste area grouping
WFO	Work for Others
WHPP	Waste Handling and Packaging Plant
WIPP	Waste Isolation Pilot Plant
WM	waste management
WOCE	White Oak Creek Embayment
WRDC	Wright Research and Development Center
WSDD	Waste Systems Data and Development

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 Headquarters DOE, 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-OR staff provided guidance at each stage of the planning process. Special appreciation goes to Lynda H. McLaren 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; electronic publishing staff; Larry Davis, for page makeup; graphic artists; photographers; and Joseph H. Lovell, for financial resources data.

In the Office of Planning and Management, we would like to thank Deborah Barnes for writing, editing, and coordinating input; Janet Dippo, Kathy Sharpe, and Rita Thearp for secretarial assistance; and Sybil Wyatt, for writing and consultation on design.

Amanda W. Renshaw

☆ U.S. Government Printing Office: 1991—649-311