

Oak Ridge National Laboratory Institutional Plan

FY 1996–FY 2001

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Contents

1. Laboratory Director's Statement.....	1-1
2. Laboratory Mission, Vision, and Core Competencies.....	2-1
3. Laboratory Strategic Plan	3-1
3.1 Situation Analysis	3-1
3.2 Strategy for the Future: Bringing Science to Life	3-3
3.3 Strategic Goals.....	3-4
4. Major Laboratory Initiatives.....	4-1
4.1 The Oak Ridge Spallation Neutron Source	4-1
4.2 The Center for Biological Sciences.....	4-2
4.3 The Advanced Materials Characterization Laboratory	4-4
4.4 Other Initiatives.....	4-5
5. Scientific and Technical Programs	5-1
5.1 U.S. Department of Energy	5-1
5.1.1 Science and Technology Programs	5-1
5.1.1.1 Office of Energy Research	5-1
Magnetic Fusion—AT	5-1
High-Energy Physics—KA.....	5-7
Nuclear Physics—KB	5-7
Heavy-Ion Physics Task—KB02	5-8
<i>Initiative: Holifield Radioactive Ion Beam Accelerator:</i>	
<i>Instrumentation Upgrade and Program</i>	
<i>Development.....</i>	<i>5-9</i>
Nuclear Theory Program—KB03	5-10
Low-Energy Nuclear Physics Program—KB04	5-10
Basic Energy Sciences—KC	5-11
Materials Sciences—KC02	5-12
Chemical Sciences—KC03.....	5-16
Engineering and Geosciences—KC04	5-19
Advanced Energy Projects—KC05	5-21
Applied Mathematical Sciences—KC07	5-21
Energy Research Analyses—KD.....	5-24
Advanced Neutron Source—KE	5-25
Multiprogram Energy Laboratories Facilities	
Support—KG.....	5-25

	Biological and Environmental Research—KP	5-25
	<i>Initiative: Computational Biosciences</i>	5-26
	Analytical Technology—Measurement	
	Science—KP01	5-27
	Environmental Research—KP02	5-27
	Health Effects and General Life	
	Science—KP03, KP04	5-31
	Carbon Dioxide Research—KP05	5-35
	Medical Applications—KP06	5-37
	Superconducting Super Collider—KS	5-39
	Laboratory Technology Applications—KU	5-39
5.1.1.2	Office of Nuclear Energy, Science and Technology	5-42
	Nuclear Energy R&D—AF	5-42
	<i>Initiative: Production of ²³⁸Pu in HFIR/REDC</i>	5-44
	Naval Reactors—AJ	5-46
	Isotope Production and Distribution Program—ST	5-46
5.1.1.3	Office of Science Education and Technical Information	5-47
	University and Science Education—KT	5-47
5.1.2	Energy Programs	5-49
5.1.2.1	Assistant Secretary for Energy Efficiency and Renewable Energy	5-49
	Electric Energy Systems—AK	5-50
	Energy Storage Systems—AL	5-50
	Geothermal Systems—AM	5-51
	Hydrogen—AR	5-51
	Hydropower—CE	5-51
	Solar Energy—EB	5-52
	Buildings Sector—EC	5-52
	Industrial Energy Conservation—ED	5-54
	Transportation—EE	5-56
	Technical and Financial Assistance—EF	5-58
	Utility Sector—EK	5-59
5.1.2.2	Assistant Secretary for Fossil Energy	5-59
	Coal—AA	5-59
	Gas—AB	5-60
	Petroleum—AC	5-61
	Innovative Clean Coal Technology—AZ	5-62
	Strategic Petroleum Reserve—SA	5-62
5.1.2.3	Energy Information Administration	5-62
	National Energy Information System—TA	5-62
5.1.2.4	Power Marketing Administrations	5-62
	Bonneville Power Administration	5-62
5.1.3	National Security and Environmental Management Programs ..	5-62
5.1.3.1	Assistant Secretary for Defense Programs	5-62
	Weapons Activities—GB	5-62
	Materials Production—GE	5-63
5.1.3.2	Assistant Secretary for Environmental Management	5-64
	Environmental Restoration	5-64

	Waste Management	5-65
	Technology Development	5-66
	Quality Assurance and Quality Control	5-67
	Compliance and Program Coordination	5-67
5.1.3.3	Office of Fissile Materials Disposition	5-67
	Fissile Materials Disposition—GA	5-67
5.1.3.4	Office of Civilian Radioactive Waste Management	5-69
	Nuclear Waste Fund—DB	5-69
5.1.4	Environment, Safety, and Health	5-70
	Assistant Secretary for Environment, Safety, and Health	5-70
	Environment—HA	5-70
	Nuclear Safety Policy and Standards—HP	5-73
5.1.5	Other DOE Programs	5-73
5.1.5.1	Assistant Secretary for Policy	5-74
	Policy Planning and Analysis—PE	5-74
5.1.5.2	Associate Deputy Secretary for Field Management ...	5-74
	In-House Energy Management—WB	5-74
5.1.5.3	Federal Energy Regulatory Commission—VR	5-75
5.1.5.4	Other Programs	5-75
5.1.6	Other ORNL Programs	5-76
5.1.6.1	Reactor Operations	5-76
5.1.6.2	Scientific and Technical Information Management	5-77
5.1.7	Integrated R&D: Building Centers of Excellence	5-82
5.1.7.1	Integration of ORNL Capabilities	5-83
	Center for Biotechnology	5-83
	Center for Global Environmental Studies	5-87
	Center for Risk Management	5-89
	Isotope Production Capabilities	5-89
	Separations and Chemical Processing	5-91
	<i>Initiative: Center for Separations and Chemical</i>	
	<i>Processing</i>	5-91
5.1.7.2	Integration of Oak Ridge Capabilities	5-92
	Instrumentation and Measurement Science	5-93
	<i>Initiative: Intelligent Measurement Systems</i>	
	<i>Laboratory</i>	5-93
	Center for Environmental Technology	5-95
	Oak Ridge Center for Healthcare Industry	
	Development	5-95
	Oak Ridge Centers for Manufacturing Technology ...	5-96
	<i>Initiative: Oak Ridge Energy and Environmentally</i>	
	<i>Sustainable Manufacturing Center</i>	5-96
	Modeling and Simulation Capabilities	5-97
	<i>Initiative: Virtual Prototyping Center</i>	5-97
	Transportation R&D	5-98
5.1.7.3	Integration of National Laboratory System	
	Capabilities	5-99
	<i>Alliance for Advanced Robotics Technology</i>	5-99
	<i>Interlaboratory Collaborations in Biotechnology</i>	5-99
	<i>Oak Ridge Center for Isotope Technologies</i>	5-100

	<i>MPLUS: Metals Processing Laboratory User Center</i>	5-101
	<i>Oak Ridge Center for Surface Engineering and Coating Technology</i>	5-102
5.2	Work for Others	5-103
5.2.1	Federal Organizations	5-104
5.2.1.1	Nuclear Regulatory Commission	5-104
	Nuclear Regulatory Research	5-104
	Analysis and Evaluation of Operational Data	5-105
	Nuclear Material Safety and Safeguards	5-106
	Other Offices	5-106
5.2.1.2	U.S. Department of Defense	5-107
	Army	5-107
	Navy and Marine Corps	5-108
	Air Force	5-109
	Military Transportation	5-110
	Defense Nuclear Agency	5-110
	Other Department of Defense Agencies	5-111
5.2.1.3	National Aeronautics and Space Administration	5-111
5.2.1.4	U.S. Department of Health and Human Services	5-111
5.2.1.5	U.S. Environmental Protection Agency	5-112
5.2.1.6	National Science Foundation	5-113
5.2.1.7	Federal Emergency Management Agency	5-113
5.2.1.8	U.S. Agency for International Development	5-114
5.2.1.9	U.S. Department of Transportation	5-114
5.2.1.10	U.S. Department of Commerce	5-115
5.2.1.11	Other Federal Agencies	5-115
5.2.2	Nonfederal Organizations	5-116
5.2.2.1	Electric Power Research Institute	5-116
5.2.2.2	American Petroleum Institute	5-117
5.2.2.3	Joint Institute for Energy and Environment	5-117
5.2.2.4	Other Nonfederal Organizations	5-117
5.3	Laboratory Directed R&D Program	5-118
6.	Critical Success Factors	6-1
6.1	Continuous Improvement	6-1
6.1.1	Reengineering ORNL	6-1
6.1.1	Monitoring and Measuring Quality of Performance	6-1
6.1.2	Quality Assurance Program	6-3
6.2	Human Resources	6-3
6.2.1	Valuing Diversity	6-3
6.2.2	Quality of Life	6-6
6.2.3	Professional Growth	6-6
6.2.4	Recognition Programs	6-7
6.3	Environment, Safety, and Health	6-7
6.3.1	ES&H Goals and Objectives	6-7
6.3.2	Current Conditions	6-8
6.3.3	ES&H Plans and Initiatives	6-8
6.3.4	Environmental Management Activities	6-11

6.4 Infrastructure and Support	6-15
6.4.1 Capital Assets Planning	6-15
6.4.2 Information Resource Management	6-16
6.5 Communication and Trust	6-17
7. Summaries of Other Plans.....	7-1
7.1 Technology Transfer Plan	7-1
7.1.1 Vision	7-1
7.1.2 Strategic Objectives	7-1
7.1.3 Resources and Staffing.....	7-2
7.1.4 Patents and Licensing	7-2
7.2 Strategic Plan for Computing	7-3
7.2.1 Vision and Strategies	7-3
7.2.2 Goals	7-6
8. Resource Projections.....	8-1
Appendix	A-1
Site and Facilities Data	A-1
User Facility Data	A-9
Science and Mathematics Education Data	A-11
Human Resources Data	A-14
Laboratory Organization Chart	A-19
Abbreviations	A-21

1 • Laboratory Director's Statement

This institutional plan for the Oak Ridge National Laboratory (ORNL) looks ahead to the start of the 21st century. In positioning the Laboratory to meet the challenges of this new century, we have recently made some significant changes in its environment.

With the merger of Martin Marietta Corporation and Lockheed Corporation to form Lockheed Martin Corporation in March 1995, ORNL's management and operating contractor since 1984, Martin Marietta Energy Systems, Inc., became Lockheed Martin Energy Systems, Inc. In April 1995, the Department of Energy authorized a two-year extension of the Energy Systems contract for operation of the Department of Energy's Oak Ridge facilities—ORNL, the Oak Ridge Y-12 Plant, and the Oak Ridge K-25 Site, informally designated the Oak Ridge Complex.

The contract extension, signed in August 1995, converted the contract for management of the Laboratory from an award-fee system to a fixed-fee arrangement, similar to that in place at the Department's other multiprogram research laboratories. The contract extension also provided for the possibility of a separate contract between the Department and a contractor other than Lockheed Martin Energy Systems for the management of ORNL.

The Laboratory's Cognizant Secretarial Officer, Dr. Martha A. Krebs, director of the Department's Office of Energy Research, has elected to request the establishment of a separate contractual relationship within Lockheed Martin Corporation to manage and operate ORNL. The ORNL portion of the existing contract between the Department and Lockheed Martin Energy Systems will be converted to a separate contract with a new corporate entity, Lockheed Martin Energy Research Corporation, which will be part of the Lockheed Martin Energy and Environmental Sector. This contract will begin on January 1, 1996.

The process of transforming the Laboratory from a component of Energy Systems into a separate organization that is interdependent with the other facilities in the Oak Ridge Complex will require extensive efforts to ensure that the Department's expectations for programmatic and operational excellence are met in the most cost-effective way—efforts that will continue after the new contract is in place, building on the extensive transition planning that has gone into setting up the new contract arrangement.

Functional relationships between the Laboratory and Energy Systems described in this institutional plan can be expected to change as the transition proceeds. However, both the Laboratory and Energy Systems are committed to supporting the Department's missions, and changes will be designed and implemented to maintain or enhance this support.

Other changes in the Laboratory's environment are resulting from the Department's contract reform initiative, strategic alignment initiative, accelerated review of directives, and responses to the recommendations of several task forces and committees charged with reviewing the Department's activities. We welcome all of these changes, and we expect that they will have far-reaching effects on how the Laboratory does business. We view them as an

opportunity to increase our competitiveness and improve our organizational and operational practices.

Such improvements will be crucial as ORNL moves into a future in which the long-term outlook for funding is uncertain. Although national support for basic research appears strong, constraints on the federal budget are likely to have an impact on research and development (R&D) for some time to come.

We expect to sharpen our focus as we find “niches” in which ORNL can claim pride of place. We also expect to find new ways of working together—with other national laboratories, with other federal agencies, and with university and industry partners—to leverage our resources and to apply our special capabilities to national needs.

The Laboratory’s *R&D Strategic Plan*, issued in the summer of 1995 to all ORNL staff members, describes the means through which we will foster the growth and health of a strong, flexible organization that is positioned to address important national challenges. It is summarized in Sect. 3.

Key elements of the Laboratory’s plans are three major facilities initiatives, described in Sect. 4, that will strengthen our capabilities:

- A high-power spallation neutron source will meet national needs for a next-generation neutron scattering source. Combined with the Laboratory’s experience in operating particle accelerators and conducting neutron scattering research, the **Oak Ridge Spallation Neutron Source** will enable the nation to carry out major research activities in areas such as biology, materials science, superconductivity, pharmaceuticals, and electronic materials.
- The **Center for Biological Sciences** will substantially enhance both ongoing and emerging programs in protein engineering, computational and structural biology, genome research, mammalian mutagenesis, gene function, and other fields. The center will make ORNL’s resources more readily available to industry for cooperative research and to southeastern universities for collaborative exchanges.
- The **Advanced Materials Characterization Laboratory** will support ORNL’s programs in synthesis, characterization, and processing of materials, which are essential for advanced materials R&D. These highly successful programs are characterized by collaborative interactions at national, regional, and local levels. The new facility will simplify and encourage joint materials research activities not only with large, established programs but also with small programs at individual universities.

The addition of these facilities to the Laboratory’s resources will enhance our ability to carry out the Department’s missions.

As indicated by the range and scope of the Laboratory’s scientific and technical programs, described in Sect. 5, the Laboratory contributes to all of the Department’s businesses: science and technology, energy resources, environmental quality, and national security. It is our conviction that, as we advance into the 21st century, we can adapt to the many changes in our environment and use them to our advantage as we continue to support the Department through broad, multidisciplinary programs that develop the science and technology needed to answer fundamental questions, solve technical problems, and address social needs.

2 • Laboratory Mission, Vision, and Core Competencies

Mission

The Oak Ridge National Laboratory (ORNL) is a Department of Energy multi-program laboratory. It is managed for the Department by Lockheed Martin Corporation. The mission of the Laboratory is to conduct basic and applied research and development (R&D) in order to advance the nation's energy resources, environmental quality, and scientific knowledge and to contribute to educational foundations and national economic competitiveness. The Laboratory collaborates with other federal agencies, industry, and universities. It is committed to excellence in all of its activities and will be operated in full compliance with environmental, safety, and health laws and regulations.

Vision

ORNL is committed to advancing the frontiers of science and technology while addressing important national and global energy and environmental needs.

The Laboratory strives to be so well recognized for its excellence that students in certain fields of science and engineering regard working at the Laboratory as an essential element in their education.

In pursuit of this vision, ORNL will create new scientific knowledge, use this knowledge to solve important problems and to create new opportunities of social value, and attract the best talent from all elements of American society. Our motto is, "Bringing science to life." To achieve this vision, it is imperative that we maintain our intellectual honesty and scientific integrity.

Core Competencies

A core competency is a distinguishing integration of capabilities that enables an organization to deliver mission results. Core competencies represent the collective learning of an organization and provide the capacity to perform present and future missions. They offer comparative advantage and are difficult to reproduce. They exhibit customer focus, mission

relevance, and vertical integration from research through applications. They are demonstrable by metrics such as level of investment, uniqueness of facilities and expertise, and national impact.

ORNL's core competencies are characterized by an integration of technical foundations in physical, chemical, and materials sciences; biological, environmental, and social sciences; engineering sciences; and computational sciences and informatics. The ability to integrate broad technical foundations to develop and sustain core competencies in support of national R&D goals is a distinguishing strength of the national laboratories. The ORNL core competencies are

- energy production and end-use technologies,
- biological and environmental sciences and technology,
- advanced materials synthesis, processing, and characterization,
- neutron-based science and technology,
- computational science and advanced computing, and
- instrumentation, manufacturing, and control technologies (an emerging core competency shared with the Oak Ridge Y-12 Plant).

Four distinguishing institutional competencies cross-cut the core competencies and the technical foundations and are important characteristics of the Laboratory as a whole:

- development and operation of national research facilities,
- R&D integration and partnerships,
- technology transfer, and
- science education.

The core competencies and the institutional competencies are described in detail in *Oak Ridge National Laboratory: Core Competencies*, ORNL/PPA-94/4.*

*J. B. Roberto et al., *Oak Ridge National Laboratory: Core Competencies*, ORNL/PPA-94/4, Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory, December 1994.

3 • Laboratory Strategic Plan

The *ORNL R&D Strategic Plan** was issued to Laboratory staff in August 1995. The strategic planning process that was carried out in developing this plan included an analysis of the current situation, selection of an overall strategy for the future, and the definition of goals and strategies. These elements are summarized here.

3.1 • Situation Analysis

For the purposes of this strategic plan, it is assumed that the Oak Ridge National Laboratory (ORNL) will remain a Department of Energy-owned, contractor-operated national laboratory and that its most important role will be providing support for the Department's missions. The Department of Energy will remain ORNL's primary sponsor. At the same time, a growing emphasis on making the resources of the national laboratories available to the entire government system—on making these institutions in fact, as well as in name, *national* laboratories—will broaden ORNL's customer base.

The Department of Energy has identified five “business lines”—science and technology, energy resources, environmental quality, national security, and economic productivity. Its primary missions are in the first four areas, with economic productivity representing a derivative and critical success indicator of these missions.

ORNL is positioned to supply the knowledge and technology that the Department needs to achieve its strategic goals in these areas. As a diversified laboratory with a broad mission carried out by a multidisciplinary staff through several major program areas, ORNL will

- apply its scientific and technical capabilities to national needs by conducting basic and applied research in an integrated program that includes extensive collaboration with universities and industry;
- conceive, develop, and demonstrate safe, economical, reliable, and environmentally sustainable technologies for efficient energy supply and use;
- provide the knowledge and technology needed to sustain, protect, and restore the environment; to enhance human health; and to support practices and policies that promote sustainable development; and
- contribute to maintaining the technology infrastructure and capabilities needed to ensure national security.

**ORNL R&D Strategic Plan*, Oak Ridge National Laboratory, May 1995. Available from the ORNL Office of Planning and Management, P.O. Box 2008, Oak Ridge, TN 37831-6251.

ORNL has an experienced and talented staff and a remarkable array of research tools. These assets will be maintained, strengthened, and focused on creating and exploring the revolutionary changes expected in the fields of science and technology in which ORNL is involved. The exploration of new technical directions will be supported through the Laboratory Directed R&D Fund, which provides financial support for innovative ideas, and through program development activities.

Demand for the knowledge and technology that are ORNL's principal products is expected to remain high. However, constraints on federal funding, coupled with the end of the Cold War, have led to intense scrutiny of the Department of Energy and its national laboratories and to calls for changes in the organization and management of the national laboratory system, focusing on efficiency, relevance to national needs, and accountability. Implementation of these changes will have an impact on the future of ORNL.

The multidisciplinary character of the Laboratory will be maintained, although fiscal pressures will mandate concentration on areas of strength and integration of complementary capabilities across the national laboratory system. The proposed establishment of "lead labs" and centers of excellence represents an opportunity for ORNL to apply and leverage the strengths embodied in its core competencies.

Integration across programmatic and organizational lines will be essential to the improved efficiency that will be demanded from the national laboratories. ORNL's institutional competency in R&D integration and partnerships represents a strength that will be of great value in coordinating resources at ORNL, within the Department of Energy's Oak Ridge complex, and across the national laboratory system. However, administrative and bureaucratic barriers to internal productivity and external collaboration must be addressed by the Laboratory and the Department.

Removal of these barriers is also a key to expanding the Laboratory's customer base. ORNL has an outstanding record in working with the private sector. More than 200 cooperative R&D agreements, more than 100 patent licensing agreements, and developments representing millions of dollars in jobs, products, and cost savings demonstrate the breadth of ORNL's institutional competency in technology transfer. In keeping with the Department's emphasis on economic productivity, ORNL will work to identify and attract new customers in government and industry.

The Laboratory's other institutional competencies—development and operation of national research facilities and science education—also support the emphasis on partnerships. In addition, they underlie a tradition of laboratory-university cooperation that will serve as a foundation for continuing efforts to strengthen basic research and support national goals for world leadership in science, mathematics, and engineering.

In all of the Laboratory's activities, cost-effective operation and improved resource management will become increasingly important as the availability of resources declines. ORNL will continue to seek creative solutions to replacing its aging infrastructure and resolving environmental "legacy issues," seeking input from stakeholders and applying technical innovations developed in its research programs.

3.2 • Strategy for the Future: Bringing Science to Life

As it advances into the 21st century, ORNL will seek new and creative ways to integrate its resources and apply them to the development of the science and technology needed to answer fundamental questions, solve technical problems, and address social needs. To extend the nation's capabilities in key areas of science and technology, ORNL proposes three major initiatives, described in detail in Sect. 4 of this plan.

- A high-power spallation neutron source will meet national needs for a next-generation neutron scattering source. Significant scientific, technical, and economic benefits derive from neutron scattering and materials irradiation research. The **Oak Ridge Spallation Neutron Source**, combined with the Laboratory's experience in operating particle accelerators and conducting neutron scattering research, will enable the nation to carry out major research activities in areas such as biology, materials science, superconductivity, pharmaceuticals, and electronic materials.
- The **Center for Biological Sciences** will substantially enhance both ongoing and emerging programs in protein engineering, computational and structural biology, genome research, mammalian mutagenesis, gene function, and other fields. The center will make ORNL's resources more readily available to industry for cooperative research and to southeastern universities for collaborative exchanges.
- The **Advanced Materials Characterization Laboratory** will support ORNL's programs in synthesis, characterization, and processing of materials, which are essential for advanced materials R&D. These highly successful programs are characterized by collaborative interactions at national, regional, and local levels. The new facility will simplify and encourage joint materials research activities not only with large, established programs but also with small programs at individual universities.

To foster the growth and health of a strong, flexible organization that is positioned to address important challenges, strategic goals have been defined in three broad areas.

- Institutional goals are directed toward maintaining the Laboratory's foundations, to ensure that ORNL possesses the strengths needed for current and future missions, and toward making these strengths available through partnerships, technology transfer, and education.
- Programmatic goals are directed toward mission execution. Goals are presented for five core competencies:
 - energy production and end-use technologies;
 - biological and environmental sciences and technologies;
 - advanced materials synthesis, processing, and characterization;
 - neutron-based science and technology; and
 - computational science and advanced computing.
- Operational goals have been established to reflect the Laboratory's commitment to excellence in its business practices. These goals address the critical success factors of the Department of Energy's strategic plan: environment, safety, and health; management practices; human resources; and communication and trust. Our aim is to operate ORNL in a manner that supports our mission, meets the expectations of our customers, expedites the performance of research programs, and is rewarding to our staff.

3.3 • Strategic Goals

3.3.1 • Institutional Goals: Laboratory Foundations

ORNL's institutional goals are closely linked to the science and technology goals of the Department's strategic plan. They are focused on the development and application of the technical foundations, core competencies, and institutional competencies identified through the Laboratory's strategic planning efforts.

- Goal 1.** Develop and enhance technical foundations and core competencies that support DOE missions.
- Goal 2.** Design, construct, and operate world-class user facilities.
- Goal 3.** Extend the Laboratory's resources to a broad customer base through partnerships, technology transfer, and science education.

3.3.2 • Programmatic Goals: Mission Execution

The Laboratory applies its core competencies to helping the Department achieve its missions. Abbreviations following each programmatic goal indicate the business lines that the goal supports: S&T for science and technology, EN for energy resources, EQ for environmental quality, NS for national security, and EP for economic productivity. Many activities support multiple business lines, indicating ORNL's ability to integrate its strengths and address diverse challenges that transcend disciplinary boundaries.

3.3.2.1 • Energy Production and End-Use Technologies

- Goal 1.** Respond to changing national policies on fission energy and nuclear materials while maintaining a record of achievement and excellence in nuclear technology and safety R&D. (S&T, EN, NS)
- Goal 2.** Host the nuclear technology phase of the U.S. fusion program. (S&T, EN)
- Goal 3.** Develop and deploy innovative systems for the clean and efficient use of fossil, renewable, and alternative fuels. (S&T, EN, EQ, EP)
- Goal 4.** Improve the efficiency and reduce the environmental impact of systems for energy delivery and use. (S&T, EN, EQ, EP)
- Goal 5.** Develop and deploy new tools and technologies that lead to safe, sustainable transportation systems. (S&T, EN, NS, EP)

3.3.2.2 • Biological and Environmental Sciences and Technology

- Goal 1.** Advance fundamental understanding of the molecular basis of gene and protein function. (S&T, EN, EQ, EP)
- Goal 2.** Restore and enhance the capability for producing and separating isotopes for medical, industrial, and national research needs. (S&T, EQ, EP)

- Goal 3.** Reduce the risk to human health from exposure to hazardous chemicals and radio-nuclides, and improve human welfare through biomedical research. (S&T, EN, EQ)
- Goal 4.** Improve the understanding of environmental processes and develop a scientific basis for implementing environmental technologies (monitoring, mitigation, and remediation). (S&T, EN, EQ, EP)
- Goal 5.** Develop the scientific basis and deploy techniques for supporting socially and environmentally responsible technology development and options for sustainable development. (S&T, EN, EQ)

3.3.2.3 • Advanced Materials Synthesis, Characterization, and Processing

- Goal 1.** Develop, enhance, and promote the advanced materials synthesis, characterization, and processing competency to address national needs in energy, the environment, and economic competitiveness. (S&T, EN, EQ, EP)
- Goal 2.** Enhance partnerships in materials science R&D. (S&T, EN, EQ, EP)
- Goal 3.** Provide infrastructure to support world-class materials research. (S&T, EN, EQ, EP)

3.3.2.4 • Neutron-Based Science and Technology

- Goal 1.** Gain academic and industrial recognition of the Laboratory's neutron science facilities and capabilities as necessary and unique national assets. (S&T, EN, EP)
- Goal 2.** Strengthen and enhance ORNL's neutron-based science and technology programs to improve research excellence, collaborations, and relevance to a broad range of scientific disciplines. (S&T, EN, EQ, NS, EP)
- Goal 3.** Design, construct, and operate a high-power spallation neutron source to provide an unparalleled facility for neutron science and technology. (S&T, EN, EQ, EP)

3.3.2.5 • Computational Science and Advanced Computing

- Goal 1.** Build a world-class program in computational science. (S&T, EN, EQ, EP)
- Goal 2.** Create a high-performance computing and communication environment that supports the requirements of Grand Challenge research. (S&T, EP)
- Goal 3.** Assist industry in the application of computing to analysis, design, and manufacturing. (S&T, EP)
- Goal 4.** Develop and deploy numerical algorithms for solving large-scale scientific and engineering problems. (S&T, EN, EQ, EP)
- Goal 5.** Advance the use of high-performance computing and communications in university and precollege educational programs. (S&T, EP)

3.3.3 • Organizational Effectiveness

Operational goals have been established to reflect the Laboratory's commitment to excellence in its business practices. These goals address the critical success factors of the Department of Energy's strategic plan: environment, safety, and health; management practices; human resources; and communication and trust.

Goal 1. Conduct all operations in a safe and environmentally responsible manner.

Goal 2. Significantly reduce the cost of doing business by using best business practices.

Goal 3. Revitalize the Laboratory infrastructure.

Goal 4. Recruit and retain the staff needed to achieve programmatic goals.

Goal 5. Improve ORNL relationships with internal and external customers.

4 • Major Laboratory Initiatives

4.1 • Spallation Neutron Source

Neutron science is one of the few remaining areas where new scientific breakthroughs are limited by the intensity available from the source. Synchrotrons and lasers have largely removed this limitation for light and X rays, but neutrons, as vital as they are for so many areas of science, are severely intensity limited. The need for a new, intense source of neutrons is urgent, and because it will take at least five to ten years to design and construct such a source, it is essential to start now to meet the nation's future needs in neutron science.

Neutrons used in scientific research are produced in two ways. The more familiar way is to bring together, in a reactor, enough fissionable material to sustain a controlled nuclear chain reaction that produces excess neutrons. The second method is spallation, in which neutrons are produced by bombarding virtually any nucleus with energetic particles (usually protons) from a high-energy accelerator. A schematic of a pulsed spallation neutron source is shown in Fig. 4.1.

The Department of Energy (DOE) has worked closely with the science community since the early 1970s in planning for the future needs for neutron sources. In January 1993,

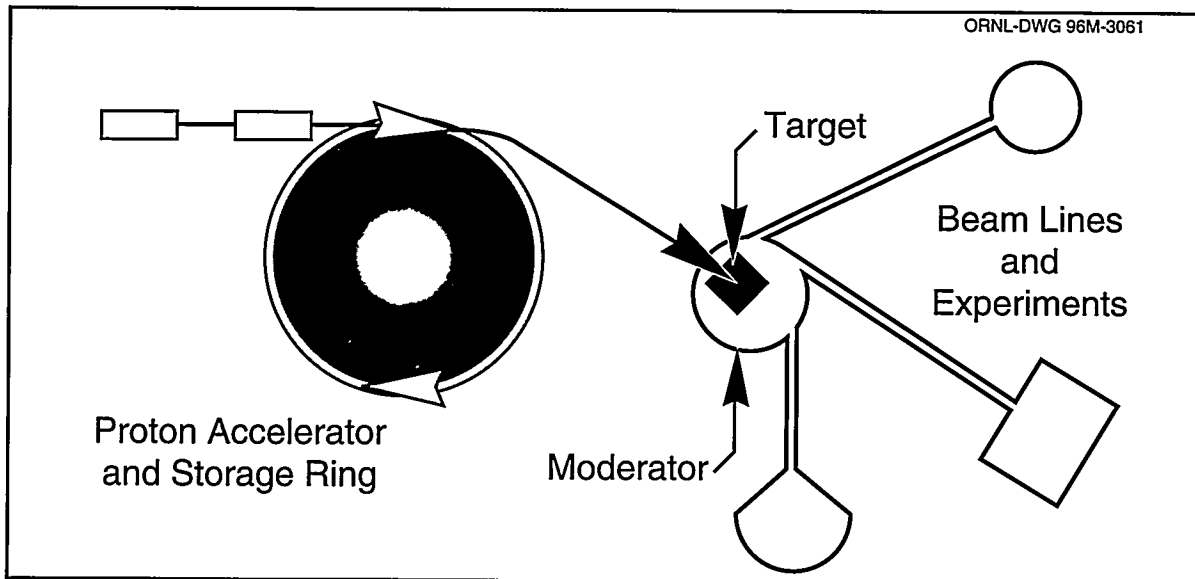


Figure 4.1

In this schematic of a pulsed spallation neutron source, energetic protons are accelerated and formed into short pulses before being directed onto the target. Each pulse of protons produces a burst of neutrons as a result of the spallation process. The neutrons are moderated and transmitted into a beam room, where they can be used in a wide variety of neutron science experiments.

DOE's Basic Energy Sciences Advisory Committee (BESAC) Panel on Neutron Sources for America's Future provided a comprehensive assessment of the needs and options for new neutron facilities that would provide the United States with sources competitive with those now in operation in Europe and Japan. This study also eloquently summarized the broad uses and future opportunities for neutrons in science and technology.

One of the primary recommendations of the BESAC Panel was the development of a new high-power spallation neutron source. DOE responded to this recommendation by providing \$500,000 to ORNL in FY 1995 for initial scoping studies on the spallation neutron source and by requesting, in the President's Budget for FY 1996, funds for research and development (R&D) and a conceptual design of the spallation neutron source.

In the President's Budget, ORNL was designated the preferred site for the spallation neutron source because of the Laboratory's broad expertise in materials science and neutron scattering, its experience in the operation of accelerators, and its project experience in designing major neutron sources. For FY 1996, DOE is providing nearly \$8 million to ORNL for the preparation of a conceptual design for the Oak Ridge Spallation Neutron Source (ORSNS). The proposed ORSNS will provide U.S. scientists with the most intense pulsed neutron source in the world, and it will become the foremost center for new fundamental science and industrial applications.

To exploit the ORSNS and the attendant benefits of neutron-based research within the area, ORNL will establish an Institute for Neutron Sciences (INS) as a joint venture of the Laboratory, the University of Tennessee (UT), and regional universities. Financial support for conceptual design of the INS is sought from the state of Tennessee through UT.

The INS will support the ongoing research and graduate education programs of UT and other regional universities by providing a site at ORNL for students and faculty to conduct joint research at the ORSNS; by increasing access to ORNL resources, such as the High Flux Isotope Reactor and the materials user facilities and staff; by holding workshops; and by otherwise promoting enhanced interaction among university, industry, and national laboratory researchers. The INS will consist of offices for collaborating regional scientists and guests, as well as conference and teleconference facilities to provide scientific interchange through broadcasts of seminars, lecture series, workshops, and other significant technical presentations and discussions. The INS will be constructed adjacent to ORNL at an approximate cost of \$8 million.

4.2 • Center for Biological Sciences

The Center for Biological Sciences (CBS) is proposed in order to ensure the viability of ORNL's highly productive and widely acclaimed Biology Division. The CBS will support advances in

- sequencing the human genome,
- developing mouse models for human disease,
- designing new proteins, and
- understanding gene function.

The CBS will bring the Laboratory's Biology Division, currently housed at the Oak Ridge Y-12 Plant, to the west end of the main ORNL site. It will enable staff scientists and students in the University of Tennessee–Oak Ridge Graduate School of Biomedical Sciences

to significantly increase their interactions with their colleagues in related research divisions at ORNL, substantially enhancing both ongoing and emerging research programs in protein engineering, computational and structural biology, genome research, mammalian mutagenesis, molecular genetics, and other fields. A major factor in the enhancement will be the increased attractiveness of the facilities to industry for cooperative research and to southeastern universities for collaborative exchanges.

The present Biology Division facilities at Y-12 are nearly 50 years old and are obsolete. Their deteriorated condition impedes both ongoing and proposed research and escalates associated costs. Inherent structural deficiencies in the mouse facility, recognized as a unique national treasure, threaten retention of accreditation so vital to reputable animal research. Studies show that retrofitting existing buildings to meet present needs and increasingly rigorous environmental, safety, and health (ES&H) standards would cost at least as much as a new building; preliminary estimates also project significant savings in operating cost resulting from moving out of the present facilities. The 13-km separation of current Biology Division facilities from the main ORNL site hampers collaborative efforts on key initiatives such as structural biology (interaction with the Solid State Division and the High Flux Isotope Reactor) and computational biosciences (interaction with the Center for Computational Sciences and the Computer Science and Mathematics Division) as well as interactions with the Health Sciences Research Division, the Environmental Sciences Division, the Chemical and Analytical Sciences Division, and others. The proposed CBS will support many ORNL programs with new and meaningful collaborative strengths.

The CBS will include animal quarters for the large and unique mouse colony, research laboratories, offices, a computer center, and a variety of specialized facilities (e.g., barrier areas for working with pathogen-free animals or hazardous materials, transgenic mouse facilities, a histology service laboratory, tissue culture laboratories, glassware and media kitchens, and X-ray crystallography facilities).

Funding for the CBS is being pursued through the Office of Health and Environmental Research (OHER) in DOE's Office of Energy Research. A site in the West End Development Area of ORNL was selected in 1991. The Project Plan and Mission Need Statement were completed in FY 1992. A new Conceptual Design Report was approved and validated in spring 1995. Pre-Title I activities have been initiated, and many have been completed. The Site Topographic Survey and the Rare and Endangered Species Survey have been completed, as have the Archeological Reconnaissance, the Security Plan, the Quality Assurance Plan, and the Safety Analysis and Review. The geotechnical investigation and wetlands assessment have also been completed, and the environmental assessment has been drafted and submitted for comment. Other necessary documents, such as the System Requirements Document and the design criteria, are in preparation. A revised project data sheet (schedule 39-3) was submitted to the Office of Energy Research in June 1995, and a Field Work Proposal (FWP) has been submitted to OHER for operating funds to support the CBS as a construction line item and to complete the necessary supporting data. The annual CBS budget validation review was held by teleconference in May 1995.

4.3 • Advanced Materials Characterization Laboratory

A 1989 study by the National Research Council demonstrates that materials science and engineering (MS&E) is one of the most rapidly developing areas of R&D—one that is vital to the future competitiveness of the United States in the international marketplace. Cutting-edge research and close cooperation among universities, industries, and national laboratories are needed to carry ideas from inception to the marketplace in a timely manner. A national plan drafted by the Office of Science and Technology Policy as a follow-on to the National Research Council study forms the basis for increased emphasis on materials R&D at a national level.

ORNL has one of the strongest and broadest materials sciences programs in the nation. In areas such as materials characterization, high-temperature intermetallics, and advanced ceramics, its successes are unparalleled. It is an extremely attractive place for collaborative research with universities and industries across the United States because of resources such as the High Flux Isotope Reactor, the Shared Research Equipment Program, the Surface Modification and Characterization Research Center, and the High Temperature Materials Laboratory and because of its extensive experience in technology transfer through cooperative R&D agreements (CRADAs) and licensing. Regional interactions have just begun to take advantage of the numerous innovative materials R&D programs that collectively span an extremely broad range of disciplines, in part because these programs are located at universities and colleges in the southeastern United States.

To make the ORNL materials sciences resources more useful, attractive, and available for joint cooperative projects, we previously proposed to centralize all materials R&D taking place at ORNL. However, a cost assessment revealed that centralization of all of these diverse resources would be prohibitively expensive. The highest near-term priority identified during this assessment was the centralization of advanced materials structural characterization equipment. Electron microscopes, atom probe microscopes, and nanoindenter mechanical properties equipment are now housed in buildings that barely meet the manufacturers' requirements for optimum operation of this equipment. It is clear that these buildings will not allow ORNL to maintain state-of-the-art instrumentation for the next generation of this equipment.

The Advanced Materials Characterization Laboratory (AMCL)—a new 3,000-m² (≈32,000-ft²) structure that will provide the high-quality environment required to optimize performance of sophisticated characterization equipment essential for the next generation of advanced materials R&D—is proposed to meet these needs. The overall goal is to provide an environment that fosters the state-of-the-art materials characterization essential for understanding materials and materials-related processes and phenomena that underpin energy technologies and industrial endeavors. Construction of the facility will be guided by the underlying principles of safety, environmental consciousness, and quality engineering, integrated with the necessary environment, safety, health, and quality oversight. The total construction cost for the AMCL will not exceed \$27 million. Additional cost for the initial capital equipment is estimated at \$2 million. We propose that design begin in FY 1999 and that construction be completed in FY 2002.

4.4 • Other Initiatives

The initiatives listed below are discussed in Sect. 5. Many of these initiatives involve multidisciplinary research that supports more than one of DOE's business areas.

Science and Technology Programs

- Office of Energy Research (Sect. 5.1.1.1)
 - Holifield Radioactive Ion Beam Facility: Instrumentation Upgrades and Program Development
 - Computational Biosciences
- Office of Nuclear Energy, Science and Technology (Sect. 5.1.1.2)
 - Production of ^{238}Pu in HFIR/REDC

Integrated R&D Initiatives

- Integrating ORNL capabilities (Sect. 5.1.7.1)
 - Center for Separations and Chemical Processing
- Integrating Oak Ridge capabilities (Sect. 5.1.7.2)
 - Intelligent Measurement Systems Laboratory
 - Oak Ridge Energy and Environmentally Sustainable Manufacturing Center
 - Virtual Prototyping Center

5 • Scientific and Technical Programs

ORNL is engaged in basic and applied research and development (R&D) in all of the businesses identified in the DOE Strategic Plan: science and technology, energy resources, national security, environmental quality, and economic productivity. Programs at ORNL frequently address more than one business area, indicating the Laboratory's ability to integrate its strengths across disciplinary, programmatic, and institutional boundaries. This integration supports not only DOE programs, but also work for other federal agencies and for other sponsors.

5.1 • U.S. Department of Energy

5.1.1 • Science and Technology Programs

5.1.1.1 • Office of Energy Research

The DOE Office of Energy Research (DOE-ER) is the largest single sponsor of research at ORNL. It supports programs in magnetic fusion energy, high-energy and nuclear physics, basic energy sciences, and biomedical and environmental research.

Magnetic Fusion—AT

The ORNL Fusion Program is distinguished by extensive collaboration, both nationally (with numerous universities, industries, and national laboratories) and internationally (with ten countries), and by the breadth of its component subprograms in physics, technology, and systems studies. Work is carried out primarily in the ORNL Fusion Energy Division, with major contributions from several other ORNL divisions, from the Engineering organization of Lockheed Martin Energy Systems, Inc., and from the Oak Ridge Y-12 Plant.

The goals of the national fusion energy research program are being recast to emphasize plasma science and innovation in fusion science and technology as a central domestic theme and the pursuit of fusion energy through international partnership. ORNL supports these goals through

- theoretical and experimental studies aimed at understanding the science of fusion plasmas,
- investigation of improvements to the tokamak, as well as alternate confinement schemes,
- technology development for existing and future experiments,
- engineering design support, particularly for the International Thermonuclear Experimental Reactor (ITER), and

- the development of radiation-resistant and low-activation materials.

Support for the ORNL program comes from the DOE Office of Fusion Energy (DOE-OFE). Support for applications outside fusion comes from a variety of sources both within and outside DOE.

Fusion Theory Program • The primary emphasis of the fusion theory program is on understanding plasma confinement in tokamaks, with supporting studies of an alternative toroidal confinement concept, the stellarator/torsatron. Research focuses on the following areas:

- Analysis of anomalous transport of particles and energy. ORNL has a leadership role in the national Transport Task Force, which applies theory and experiment to gain a better understanding of transport phenomena in toroidal devices.
- Development of models for instabilities driven by alpha particles, supporting deuterium-tritium (D-T) operations in the Tokamak Fusion Test Reactor (TFTR) at Princeton Plasma Physics Laboratory (PPPL) and preparations for ITER.
- Development of plasma simulation models and computational approaches, and application of models to specific experiments for validation and improvement of the models. This effort includes ORNL's participation in the Numerical Tokamak Project, a Grand Challenge in computational science that is being addressed by a national laboratory-university consortium.
- Definition, development, and modeling of plasma fueling and heating techniques in support of edge physics and divertor performance, helium removal, and pellet fueling.
- Development of large-scale computational models for radio-frequency (rf) heating and noninductive current drive and of computational tools and techniques for the analysis and design of rf antennas.

Atomic Physics and Diagnostics Development • The Atomic Physics for Fusion Program focuses on experimental and theoretical studies of inelastic collision processes involving atomic and molecular fusion plasma impurity ions. Such data are needed to understand the behavior of plasmas in magnetically confined fusion devices and to interpret plasma diagnostics measurements. Experiments provide absolute cross sections for electron-impact excitation, ionization, and dissociation for multicharged or molecular impurity ions, and also for very low energy electron transfer between colliding heavy particles. Measurements of low-energy particle-surface interactions, an expanding part of this program, are particularly relevant to divertor designs. The experimental activity is closely coordinated with a theoretical effort, providing benchmarks for testing detailed calculations of electron-impact excitation and ionization and for fusion-relevant heavy-particle collisions.

The Controlled Fusion Atomic Data Center (CFADC) provides data on atomic and molecular processes that are relevant to fusion R&D. A bibliographic database is maintained, and recommended numerical data are available in book form and in an internationally accepted format, ALADDIN, through cooperation with the International Atomic Energy Agency. In-house data evaluation and production efforts yield important data for fusion science. Through an international consortium, the widely used Atomic Data and Analysis Structures (ADAS) suite of modeling codes and atomic data, developed by the Joint European Torus (JET) Joint Undertaking, will be made available locally. The CFADC data are now being placed on the Internet (<http://www-cfadc.phy.ornl.gov/>). Heavy emphasis will be placed on obtaining, analyzing, and publishing data that support edge physics, divertor modeling, and shield and limiter requirements for present and planned devices such as DIII-D and ITER.

In the diagnostics development program, far-infrared laser-based diagnostics for fusion alpha particles and electron density profiles are being developed. Requirements for application to ITER will be developed.

Spherical Tokamak Program • The Spherical Tokamak (ST) Program explores compact, stable low-field plasma configurations characterized by good confinement, plasma beta levels of the order of unity, a self-driven current fraction of the order of unity, and thick outboard scrape-off layers connected to naturally formed long-channel divertors. The following activities are planned:

- Collaborate with PPPL and other U.S. institutions in developing practical designs for near-term experiments and with international institutions active in ST research [e.g., on the Small Tight Aspect Ratio Tokamak (START) at Culham, United Kingdom; GLOBUS-M at the Ioffe Institute, St. Petersburg, Russia; and the Mega-Ampere Spherical Tokamak (MAST) at Culham].
- Study missions and cost-effective designs for nearer-term miniature ST fusion cores, with plasma currents of ≈ 10 MA, to test D-T burn physics and nuclear technologies.
- Study economically competitive ST demonstration and power reactors to guide the present research.

Confinement Program • The ORNL confinement program uses its core competencies to address national program priorities. These core competencies are

- edge physics and particle control,
- physics of rf heating and current drive,
- pellet fueling physics, and
- alternate concept development.

They are directed at the improvement of plasma performance, the development of optimized D-T plasma fueling scenarios, and concept improvement.

Through hardware development and active participation in experiment and theory programs, ORNL's role in the integration of physics and technology has expanded during the last three years. At present, efforts are concentrated in collaborative programs, both national (DIII-D, TFTR) and international [Tore Supra, JET, TEXTOR, ASDEX-U, the Compact Helical System (CHS), and Wendelstein VII-AS (W7-AS)]. These programs focus on techniques for understanding and controlling the plasma boundary and particle transport, pellet fueling for plasma performance and ITER scenarios, the ion cyclotron range of frequencies (ICRF) for heating and current drive, and the development of alternate confinement schemes. All of these schemes are aimed at improving plasma performance, in most cases through current and pressure profile control.

Edge Physics and Particle Control Program • The long-term goal of the ORNL edge physics and particle control program is to develop particle control techniques for advanced tokamak scenarios and steady-state plasma operation, relevant to the next generation of tokamak experiments (e.g., ITER). The focus is on dynamic control of wall effects, pellet/beam/gas fueling, and controlled exhaust of both the fuel and helium ash. The ORNL program is addressing these issues on existing tokamaks (DIII-D, Tore Supra, TEXTOR, and ASDEX-U) to develop models that can be used in specifying particle control schemes for future devices.

ORNL has a lead role in helium transport and exhaust studies on both DIII-D and TEXTOR and participates in studies on JET and ASDEX-U. Helium ash removal is a major R&D issue for ITER, and these programs are providing new data and models to improve the helium pumping schemes for future tokamaks. Edge physics measurements in progress on

DIII-D, Tore Supra, and TEXTOR will supply a database for ITER and support the validation and application of modeling codes.

RF Heating and Current Drive Physics Program • The objectives of the rf physics program are to develop efficient scenarios for ICRF heating and current drive and to assess the long-pulse performance of rf antennas in fusion-grade plasmas. Fast wave current drive (FWCD) antennas, designed and built by ORNL, are installed on DIII-D and Tore Supra. The experimental program on DIII-D emphasizes optimization of coupling and directivity in long-pulse and high-power experiments, investigation of other rf scenarios [e.g., mode-conversion current drive and pellet-enhanced performance (PEP) mode confinement], and transport analysis and modeling of rf plasmas. On Tore Supra, the focus is on studies of the performance of rf antennas in long-pulse, high-power plasmas; optimization of the antenna directivity for FWCD; and advanced performance regimes such as control shear reversal.

Pellet Fueling Physics Program • The objective of the pellet fueling physics program is to provide a flexible particle source, within the plasma, to control the plasma profiles (thereby affecting plasma performance) and to develop fueling scenarios for ITER. Pellet fueling scenarios are being developed with a multiple-shot gas gun on DIII-D and a centrifuge pellet injector on Tore Supra. Balanced operation between long-pulse pellet fueling and continuous particle removal with a pumped divertor on DIII-D and a pumped limiter on Tore Supra is a unique aspect of these collaborations. In particular, the pellet program on DIII-D will provide opportunities to study the effects of shear reversal and enhanced H-mode operation. For the D-T phase of TFTR, ORNL has provided a tritium-compatible, high-speed pellet injector and participates in the pellet fueling experimental program.

Stellarator Program • Comparative studies of stellarators and tokamaks are aimed at improving our understanding of toroidal confinement and developing an improved confinement concept. Collaborative ICRF and pellet injection experiments on W7-AS and local island divertor experiments on CHS compare particle and heat transport in tokamak and stellarator configurations, with the goal of understanding the underlying physics processes. These collaborations also provide a link for U.S. participation in the development and operation of the large next-generation stellarators now under construction in Japan and Germany.

RF Technology Development • ORNL is responsible for the technology development, design, and application of rf power on major fusion experiments whose systems will provide the development basis for ITER. The long-range goal is to develop systems that are cost-effective and compatible with operation in fusion power plants. Extensive collaborations support the development of critical areas such as ICRF current drive, phase control, long-pulse technology and physics, advanced launchers, and advanced heating scenarios. Plans include activities in the following areas:

- ICRF current drive antenna array and phase control systems. ORNL is responsible for the design of a 32-MW system for JET. ORNL is also developing the real-time matching needed for longer-pulse or steady-state machines such as ITER.
- Long-pulse technology and physics issues. The development of this technology is especially important to ITER, since this experiment has a long-pulse/steady-state mission. Again, collaborations further the state of the art. Work at ORNL has extended current drive capability to Tore Supra; this collaboration is also being used to measure how rf power modifies the edge plasma and affects antenna component lifetimes and plasma confinement. Other collaborations supporting this effort involve experiments on TFTR and DIII-D.

- Advanced launcher development and advanced heating scenarios. Waveguide antennas have much better power capability and mechanical ruggedness than conventional loop antennas. Using these attributes to full advantage on large (or high-field) machines, such as ITER, requires innovations such as the folded waveguide launcher and a way of removing the linkage between frequency and ion resonance. Tests in the ORNL Radio Frequency Test Facility indicate that the injected power density can be extended to $>20 \text{ MW}\cdot\text{m}^{-2}$ (thus reducing port size). Collaborations on TFTR, Tore Supra, and DIII-D are used to demonstrate direct electron heating techniques, which would remove the frequency link to ion resonances.

All of these collaborations support the development of advanced heating concepts and the extension of ICRF heating and current drive to other regimes.

Pellet Injector Technology Development • ORNL is a leader in developing and applying advanced plasma fueling systems for magnetic fusion. The fueling group is integrated with plasma theory, modeling, particle control, confinement, rf, and edge physics efforts at ORNL and at other fusion laboratories through extensive national and international collaborations [DIII-D, TFTR, JET, Tore Supra, Los Alamos National Laboratory (LANL), and ENEA-Frascati]. The long-range goal of this program is to develop ultralong-pulse to steady-state pellet injection systems for D-T operation at moderate ($\leq 1\text{-km/s}$) and high ($\geq 3\text{-km/s}$) velocities. Applications are divided among a number of facilities (e.g., tritium at the LANL Tritium Systems Test Assembly, TFTR, and JET; long-pulse operation at Tore Supra). In addition, the program provides specialized injector systems and expertise to support experimental programs. The ORNL program will concentrate on the following activities, with special emphasis on long-pulse particle control issues:

- Support the TFTR D-T phase with the ORNL tritium-compatible, high-speed pellet injector. The experimental program will focus on ITER-relevant plasma conditions.
- Develop long-pulse to steady-state, reliable pellet fueling systems for ITER.
- Develop high-speed (3- to 5-km/s) pellet fueling technology for ITER to provide innovative approaches for improved plasma operating regimes. A key element of this program is the collaboration with ENEA-Frascati to develop a repetitive two-stage light gas gun.
- Develop safe and reliable tritium pellet fueling technology for ITER.
- Upgrade the existing Tore Supra centrifuge injector for longer pulses (up to 2-min operation) to study particle control and transport in long-pulse plasmas in which a pump divertor is used for active particle control.

Ongoing efforts in advanced technology development and applications on large tokamaks are synergistic and result in an integrated approach to the design and fabrication of innovative, capable, and reliable fueling systems for ITER and, in the long term, for fusion power plants.

Materials Program • The Fusion Energy Materials Program focuses on the development of structural materials, ceramics, and first wall and high-heat-flux materials. These efforts are supported by DOE-OFE's neutron-interactive materials program and plasma-interactive materials program. The ORNL effort supports U.S. participation in ITER and the ultimate objective of fusion as an energy source.

Structural Materials • In the structural materials program, the primary emphasis remains on the qualification of structural materials for ITER and the development of low-activation ferritic steels, vanadium alloys, and structural ceramic composites (e.g., SiC/SiC) for future fusion power systems.

A bonded austenitic stainless steel/copper structure is the leading candidate for ITER structural material. In a collaborative program with the Japan Atomic Energy Research

Institute, we are investigating the effects of fusion damage levels on the engineering properties of austenitic stainless steels, which are the load-carrying member of this structure. Irradiation of these alloys in ORNL's High Flux Isotope Reactor with tailoring of the neutron spectrum produces damage levels (transmutation-produced helium and displacements per atom) equivalent to those that will be produced in a fusion power system. These experiments provide data and understanding of radiation response at the temperatures and damage levels required for ITER.

Development of low- or reduced-activation materials is essential to achieving fusion's potential as a safe and environmentally attractive energy source. Our work on low-activation ferritic steels focuses on the most critical or limiting property of this class of alloys: the radiation-induced shift in ductile-to-brittle transition temperature and the resulting reduction in fracture toughness. Our research on vanadium alloys focuses on their chemical compatibility with proposed fusion coolants and the effects of radiation on their fracture toughness.

The effects of irradiation on the dielectric properties of ceramic insulators are of critical importance in the design and operation of numerous components (e.g., rf heating and plasma diagnostics) in fusion experiments and future fusion power systems. We are making in situ measurements of the loss tangent during ionizing radiation and ionizing plus displacive radiation and exploring the phenomenon of radiation-induced electrical degradation (RIED), a rapid, permanent decrease in conductivity following an incubation period. Changes in the loss tangent will affect the choice of materials and the design of heating systems for ITER. RIED could have very serious implications for the selection of materials and the design of systems requiring ceramic electrical insulators.

First Wall and High-Heat-Flux Materials • Research on graphite and carbon-carbon composites is part of the plasma-interactive materials program and the high-heat-flux materials program. These materials must exhibit extremely high resistance to thermal shock, erosion, and neutron damage. Optimum thermal shock resistance is assumed to be offered by appropriately designed carbon-carbon composites (i.e., selected fibers, matrices, and architectures). Current work is directed toward the optimization of these materials for resistance to neutron damage.

Advanced Systems Program • The Advanced Systems Program focuses on the definition and conceptual design of future tokamaks. The conceptual design efforts have included engineering and technology development at ORNL and in industry. The Advanced Systems Program is also assisting in the conceptual design of an accelerator-based system for testing and developing fusion materials.

TPX • ORNL was one member of a multilaboratory partnership led by PPPL to design and build the TPX advanced tokamak. In the physics area, ORNL had a lead role in rf systems, edge physics, and particle control and carried out supporting work in modeling and analysis of fueling, magnetics, and plasma transport. In technology, ORNL's primary areas of responsibility were rf systems, vacuum pumping, remote handling, and shielding.

The TPX project has been terminated because of funding constraints. The project team remains available to assist with other studies and planning efforts connected with the redefinition of the fusion program.

ITER • ORNL provides the ITER program with expertise in design engineering, physics, plasma technology, fusion materials, and systems analysis. Several ORNL scientists and engineers serve as U.S. ITER Task Area Leaders in areas such as plasma performance, rf systems, containment structures, remote handling, structural materials, and design integration. Several ORNL employees also serve as members of the Joint Central Team (JCT).

ORNL expects to continue carrying out a number of ITER-related design (physics and engineering) and R&D tasks. In physics design support, ORNL areas of responsibility are plasma performance and coordination of physics-safety interface activity within the JCT and ITER partners. In engineering design and technology R&D, primary areas of responsibility include containment structures, remote handling, structural materials, pellet fueling, and rf systems. Responsibility for project drawings, computer-aided design and manufacturing, a data management system, and engineering design integration are other important ORNL activities.

International Fusion Materials Irradiation Facility • ORNL staff members are participating in an international design effort to develop a concept for an accelerator-based beam target system for the production of high-energy (14-MeV) neutrons, simulating a D-T fusion spectrum. The International Energy Agency (IEA) has established an implementing agreement for the International Fusion Materials Irradiation Facility design activity, involving representatives from Japan, Euratom, the United States, and the Russian Federation. An industrial consortium led by Grumman Aerospace Corporation is under contract to ORNL to provide the engineering design work. The Oak Ridge reservation would be an attractive site for such a facility.

Small ST Fusion Core • The Spherical Tokamak (ST) Research Program has collaborated with the University of California at Los Angeles, the University of Wisconsin, TSI Research, and the Efremov Institute of the Russian Federation in developing the physics and design concepts for ST fusion cores. Such fusion cores are small (major radii ≈ 1 m) and relatively modest in D-T-fueled fusion performance (fusion power 30–100 MW) but can provide high neutron wall loading (0.5–3 MW/m²). They have attractive potential applications to testing fusion burn and nuclear components and to destroying fission actinide wastes.

Technical and Scientific Applications • The application of fusion science and technologies to problems outside the fusion area has become an increasingly important part of Fusion Energy Division activities and now provides some 20% of the Division budget. Fusion technology has been successfully applied to waste remediation using microwaves and cryogenic pellets, improved materials production techniques using microwaves and rf waves, plasma processing of materials, and superconductivity development and applications. This technology transfer has included work for others (funding through industry and other federal agencies), cooperative R&D agreements, and licensing of ORNL patents to industry. A goal of the Division is to expand these applications by 20% a year for the next few years.

High-Energy Physics—KA

The High-Energy Physics Program at ORNL is focused on detector design and response data for detector collaborations, on radiation shielding design, and on the development of calculational methods that will make possible definitive high-energy transport calculations. The efforts associated with the joint high-energy physics program among ORNL, the University of Tennessee, and other Southern Association for High Energy Physics universities (in particular, Duke University, the University of Virginia, and the University of Mississippi) are expected to continue.

Nuclear Physics—KB

The Nuclear Physics Program emphasizes basic nuclear physics research, both experimental and theoretical, and operation of two facilities: the Holifield Radioactive Ion Beam

Facility, an upgrade of the Holifield Heavy Ion Research Facility that will begin operation as a user facility in FY 1996, and the Oak Ridge Electron Linear Accelerator. Research is carried out at these two facilities by ORNL staff and by visiting scientists from around the world.

Heavy Ion Physics Task—KB02 • The Heavy Ion Physics Task supports research programs in both medium-energy and relativistic heavy ion physics. These programs use accelerator facilities at several laboratories around the world.

The medium-energy research is concerned primarily with the investigation and characterization of the fundamental modes of nuclear excitation. This research program involves the study of the most collective of nuclear excitations: giant multipole resonances. In these studies the resonances are excited using medium-energy projectiles ranging in mass from protons to heavy ions. Each hadronic probe offers a unique selectivity for the excitation of various resonance modes. Of particular importance to these studies is the Coulomb excitation of giant resonances using medium-energy heavy ions. Through Coulomb excitation, both isoscalar and isovector giant resonances are excited with very large cross sections and peak-to-continuum ratios. This work also depends heavily on the measurement of the photon decay from the giant resonances using large arrays of BaF₂ detectors. New directions include studies of resonance strength in unstable nuclei, produced as beams at high-energy radioactive beam facilities, and a systematic exploration of two-phonon strength involving the giant dipole resonance. Some research effort is devoted to the study of the dynamics of collisions between complex nuclei.

At higher energies, heavy ion reactions are studied with ultrarelativistic projectiles of 200 GeV per nucleon at the Super Proton Synchrotron, located at the European Laboratory for Particle Physics (CERN) in Geneva, Switzerland. The primary purpose of this research is to study the production and characteristics of the quark-gluon plasma that may be formed in reactions between nuclei at these energies. The quark-gluon plasma is a state of matter in which quarks and gluons, the constituents of nucleons, are deconfined over volumes of nuclear dimensions. It is believed that the entire universe existed in this state for a few instants after the “big bang” of its creation. ORNL plays a major role in the CERN-based experiments WA93 and WA98. In these experiments, emphasis is placed on measurements of photons, which—because of their nearly noninteracting properties—constitute one of the best probes of early reaction phases. ORNL built and operated the calorimeters for the now completed WA80 experiment and has made a major contribution to the photon-detection capabilities of WA93 in the form of readout electronics.

If a quark-gluon plasma is formed at the near-threshold energies of the CERN Super Proton Synchrotron, it will be a baryon-rich plasma. In contrast, energies available at the Relativistic Heavy Ion Collider (RHIC) under construction at Brookhaven National Laboratory (BNL) are expected to lead to a relatively baryon-free plasma dominated by created particles. ORNL has a leadership role on one of the two major detectors, the Pioneering High-Energy Nuclear Interaction Experiment (PHENIX), under construction for the RHIC. This detector emphasizes measurements of electrons, muons, and photons. Because of their penetration properties, leptons, like photons, are considered to be excellent probes of the quark-gluon plasma. A certain fraction of muon and electron pairs results from the decay of vector mesons, the properties of which are likely to be a good signal of creation of dense matter and of deconfinement. ORNL participates in a number of PHENIX R&D activities, and the Deputy Spokesperson of this \$70 million experiment is an ORNL staff member.

Initiative

Holifield Radioactive Ion Beam Facility: Instrumentation Upgrade and Program Development

The accelerators of the former Holifield Heavy Ion Research Facility have been reconfigured to provide a capability for producing and accelerating radioactive ion beams (RIBs). This project, which began in July 1992, was completed in late FY 1995. This initiative builds on a long-range plan to provide a world-class center for nuclear structure physics and nuclear astrophysics at ORNL.

The beams from the upgraded facility, renamed the Holifield Radioactive Ion Beam Facility (HRIBF), will provide a unique capability for research. The combination of the Oak Ridge Isochronous Cyclotron and the 25-MV electrostatic tandem accelerator provides the capability to produce a large variety of low-energy, proton-rich, radioactive heavy ion beams. The availability of these accelerators and of an appropriately shielded target room for the Isotope-Separator-on-Line source offers a quick, cost-effective method for producing RIBs. Using the 25-MV electrostatic tandem accelerator (which was designed to accept low-energy, negatively charged heavy ions) as the postaccelerator for the facility allows the production of beams of heavy ions up to mass 80 for nuclear structure studies and even heavier for astrophysics. More than 100 new proton-rich compound systems can be produced using stable targets and the beams initially expected from the facility. Many of these systems are of special interest for studies in nuclear physics and nuclear astrophysics. The addition of neutron-rich RIBs produced from proton-induced fission is planned for FY 1998.

The HRIBF contains a considerable amount of nuclear structure research equipment from the Holifield Heavy Ion Research Facility. In addition, two new experimental

stations are being constructed to fully exploit the scientific opportunities for nuclear structure and nuclear astrophysics that will be provided by the RIBs.

The new nuclear structure experiment station comprises a recoil mass spectrometer (RMS) and arrays of detectors located both at the target position and at the focal plane of the RMS. The RMS, which was installed in FY 1995, will be used to isolate the rare nuclear reaction products of interest from the beam particles and other reaction products. This device, which has an unmatched capability for the study of very weakly produced isotopic species, is an excellent tool for the study of RIB-induced reactions leading to proton-rich nuclei extremely far from the stable nuclei that exist in nature. An array of high-resolution gamma-ray detectors, light charged particle detectors, and neutron detectors is being constructed around the target to detect the prompt radiation associated with the nuclear reaction. Besides detectors for determining the mass and charge of the products of a nuclear reaction, a variety of other detectors are being constructed at the RMS focal plane for measuring the radiation associated with the decay of the reaction products. Late in the decade, Gammasphere, the large national gamma-ray detector, is expected to replace the gamma-ray detectors at the target position of the nuclear structure experimental station for about a year.

The ORNL nuclear astrophysics research program will focus on using the HRIBF to directly measure nuclear reactions occurring in stellar explosions. These measurements will employ a dedicated experimental station centered on the Daresbury Recoil Separator (DRS). The DRS, valued at \$3 million, was transferred to ORNL from

the Daresbury Laboratory in England. It is currently being installed and equipped with a new target chamber, a new segmented surface barrier detector in the target chamber, and one new microchannel plate focal plane timing detector. These detectors will supplement the two that were used with the DRS in England. Future equipment planned for the DRS includes a moving tape system

and associated detectors, to implant radioactive species and measure their decay, and a hydrogen and helium gas jet target to provide ultrapure target nuclei for these important astrophysics experiments.

Budget projections for continuing development of the HRIBF are given in Table 5.1.

Table 5.1
Budget projections by fiscal year for continuing development of
the Holifield Radioactive Ion Beam Facility
(\$ in millions—BA)

	1996	1997	1998	1999	2000	2001
Operating expense	5.0	6.5	6.7	6.9	7.1	7.3
Capital equipment	1.6	1.8	1.6	1.4	1.4	1.4
Accelerator Improvement Project	0.4	0.4	0.4	0.4	0	0

Nuclear Theory Program—KB03 • The nuclear theory effort centers on basic research on low-energy nuclear structure and nuclear astrophysics and on relativistic heavy ion physics. The relativistic heavy ion program provides support and guidance for the experimental programs at CERN and BNL and entails calculations with models of hadronic evolution and hadronization. Research in nuclear structure theory takes advantage of the opportunities presented by the joint ORNL–University of Tennessee nuclear structure theory program. This program emphasizes three important themes: (1) the opportunities in traditional nuclear structure physics offered by radioactive ion beam (RIB) physics, (2) the new interface between nuclear structure physics and nuclear astrophysics afforded by RIBs, and (3) the opportunities provided by a new generation of massively parallel supercomputers for both nuclear structure and nuclear astrophysics calculations. Studies in this area include nucleosynthesis, beta decay, numerical simulations of type II supernova explosions, and nuclear reaction calculations for proton-rich nuclei. Part of the theory activities will focus on the computational Grand Challenge on the quantum structure of matter. This project is interdisciplinary in scope and involves collaborations among nuclear, atomic, and condensed matter physics. This research will support a new level of computational nuclear structure physics, primarily to perform algorithm development and support for massively parallel calculations.

Low-Energy Nuclear Physics Program—KB04 • The major task supported by the Low-Energy Nuclear Physics Program is the new program in radioactive ion beam physics, made possible by the modification of the Holifield Facility to produce RIBs. The nuclear structure program will extend the studies of nuclear properties to exotic nuclei not now accessible with stable beams. Studies of such less stable nuclei have a large potential for revealing new phenomena. Among the important nuclear structure issues that can be addressed with proton-rich RIBs are the limits of stability of very proton-rich nuclei, the proton-neutron interaction, new exotic nuclear shapes, the shell closure at double-magic

^{100}Sn , tests of fundamental symmetries in self-conjugate ($N = Z$) nuclei, transfer reactions with proton-rich nuclei, and the isospin dependence of sub-barrier transfer reactions.

The nuclear astrophysics program at the Holifield RIB Facility (HRIBF) is a new effort established to use RIBs to make pioneering advances in our understanding of novae, supernovae, X-ray bursts, and other stellar explosions. The goal of the program is to determine quantitative details of these spectacular events, such as their time scales, their time-dependent temperature and density profiles, and the abundances of nuclei produced. Because astrophysical models using stable-beam studies have been unable to yield consistent qualitative descriptions of such events, our program provides an exciting and long-awaited opportunity for the nuclear astrophysics community.

The ORNL nuclear astrophysics program will be unique, since the HRIBF will be the only U.S. facility able to produce and accelerate high-intensity, low-energy, tandem-quality beams of radioactive nuclei. We will achieve our goals by measuring absolute cross sections of (p, γ) and (α, γ) reactions on proton-rich radioactive nuclei that occur in stellar explosions, exploiting the strong overlap of the required radioactive nuclear beams and the beams at the HRIBF. Measurements will be made with an experimental system centered on the Daresbury Recoil Separator acquired from the Nuclear Structure Facility at the Daresbury Laboratory in England. This program will be integrated with stable-beam experiments and on-site theoretical efforts to fully realize the astrophysical implications of our measurements and to guide future work. In addition, it will have close ties to neutron-capture measurements made on the Oak Ridge Electron Linear Accelerator (ORELA) to understand the stellar synthesis of very heavy elements.

Late in the decade, when neutron-rich RIBs become available from the HRIBF, the new scientific topics that can be addressed will include the structure of nuclei near double-magic ^{132}Sn r-process nucleosynthesis, nuclei approaching the limits of neutron stability, and complete spectroscopy by overlapping high- and low-spin data in the same nucleus.

The Low-Energy Nuclear Physics Program also supports operations and research at ORELA, a unique, intense pulsed-neutron-source accelerator facility for reaction measurements by time-of-flight neutron spectrometry. Neutron cross sections and related quantities are measured over the entire range from 0.001 eV to about 80 MeV.

The ORELA program is directed toward basic research in nuclear astrophysics and fundamental interactions. Current effort is focused on measurement and analysis of neutron capture and total cross sections for isotopic materials that are important for improved understanding of the astrophysical s-process. Measurements of other reactions important to nuclear astrophysics, including neutron-induced charged-particle reactions, are planned. The fundamental interaction program is centered on precise neutron transmission measurements designed to resolve controversy over values of the neutron charge radius and polarizability. Measurements use existing detectors, data acquisition systems, experimental equipment, and data analysis tools developed for the earlier program in nuclear data measurement for applied needs.

Basic Energy Sciences—KC

The Basic Energy Sciences (BES) Program supports a broad spectrum of research in the physical sciences at ORNL. The two largest subprograms are Materials Sciences (KC02) and Chemical Sciences (KC03), with additional work in Engineering and Geosciences (KC04). The Office of Computational and Technology Research sponsors exploratory

research in Advanced Energy Projects (KC05) and a growing computational science program in Applied Mathematical Sciences (KC07).

Central to the BES Program is the national initiative for an Advanced Materials and Processing Program (in KC02). Key issues facing the program include development of the Oak Ridge Spallation Neutron Source (ORSNS) and the Advanced Materials Characterization Laboratory (AMCL) described in Sect. 4. Another important issue involves the continuing operation of the High Flux Isotope Reactor (HFIR). It is important to maximize HFIR's utility for neutron scattering, isotope production, irradiation, and activation programs and to increase its efficiency and effectiveness in user interactions and technology transfer. Operation of HFIR is discussed in Sect. 5.1.6.1.

Materials Sciences—KC02 • The Materials Sciences subprogram supports fundamental materials R&D including neutron scattering; synthesis and characterization of new materials; high-temperature materials; ceramic processing; superconductivity; ion beam, laser, and plasma processing; and theoretical studies for advanced energy-related materials. This subprogram also supports four user programs that hosted nearly 400 guest users in FY 1994. Two are co-sponsored by ORNL and the Oak Ridge Institute for Science and Education (ORISE): the ORNL-ORISE Synchrotron Organization for Advanced Research (ORSOAR) and the Shared Research Equipment (SHaRE) Program. The others are the Surface Modification and Characterization Research Center (SMACRC) and the neutron scattering research facilities at HFIR. Two of the Laboratory's major initiatives are in the materials sciences: the ORSNS and the AMCL, both discussed in Sect. 4. Funding for the core program is expected to increase during the planning period.

Metallurgy and Ceramics Program—KC02 01 • The BES Division of Materials Science (DMS) Metallurgy and Ceramics Program provides the scientific leadership and fundamental framework required for the development of innovative advanced materials, processes, and characterization technologies. At ORNL, this program supports research activities in the Metals and Ceramics Division and a New Initiative in the Solid State Division. It includes the research components required to better understand and use materials: synthesis, processing, fabrication, characterization, and the development of models and mechanistic understanding.

Interactions with scientists from universities, industry, and other national laboratories are an important part of the program. ORNL's basic research program is integrated with the R&D efforts of other DOE programs and of industry. At ORNL, the DMS effort has close ties to the DOE technology programs, especially the materials-related efforts funded by the Office of Energy Efficiency and Renewable Energy (DOE-EE), the Office of Fossil Energy (DOE-FE), and the fusion program in DOE-ER, as well as the Nuclear Regulatory Commission. In addition, more than 16 cooperative R&D agreements (CRADAs) with industry have grown from tasks funded by the DMS Metallurgy and Ceramics Program at ORNL. The SHaRE Program provides access to ORNL's advanced analytical microscopes, the Van de Graaff accelerator facility, and the nanoindenter. ORSOAR supports an intense X-ray beam line station at the National Synchrotron Light Source. Budgetary constraints and the upcoming University-National Laboratory-Industry Collaborative Access Team (UNI-CAT) beam line on the Advanced Photon Source at Argonne National Laboratory require discussions of current operations and offer opportunities for redefining these user programs.

Research in synthesis and processing science includes the development of fabrication and joining techniques for advanced intermetallic alloys, ceramics, and composite structures. Intermetallics research includes fundamental studies of phenomena related to physical and

mechanical properties, ranging from atomic bonding to environmental embrittlement. Processing-related research includes studies of reaction sintering, $\text{Nd}_2\text{Fe}_{14}\text{B}$ magnet materials, and novel composite materials. Building on alloy design and theory efforts, ORNL is a partner with the Idaho National Engineering Laboratory in a BES New Initiative proposal in the area of hydrogen storage materials.

Investigations in the ceramics task are focused on the establishment of basic microstructure-property relationships for the design of advanced ceramics and ceramic composites, including self-reinforced silicon nitrides. Under the BES Center of Excellence in Synthesis and Processing of Advanced Materials, R&D efforts on magnet materials and toughened ceramics for gaseous corrosion protection have been strengthened. ORNL leads the project on Mechanically Reliable Scales and Oxides for protection from corrosive environments.

A strong first-principles theory effort is integrated with the intermetallics and related alloy design efforts. Although in its infancy, a first-principles ceramics effort is growing. The understanding of materials properties and the first-principles codes developed under this program are now being used in a CRADA funded by the Office of Defense Programs (DOE-DP) with IBM and a number of the DOE-DP laboratories to investigate the giant magneto-resistance effect for magnetic memory devices.

The welding and joining program investigates the evolution and stability of microstructures and properties of weldments, including mathematical modeling and experimental verification of transport phenomena. This task includes active participation in the Center of Excellence focused project on welding. The modeling component of this task also includes the basic component of related solidification modeling efforts, including superplasticity or high-rate deformation process modeling. The modeling work is integrated in the Center of Excellence focused project on forming. Expansion of the modeling effort is planned.

Important to all of these tasks are the development and application of advanced characterization techniques, including analytical electron microscopy, scanning transmission electron microscopy (e.g., Z-contrast techniques), atom probe field ion microscopy, the mechanical properties microprobe, and ion beam techniques. Ion implantation is used to study defect interactions and radiation effects and to modify surface-related properties of polymers and ceramics. Initial experiments have been performed with the high-temperature mechanical properties microprobe. During the past year, a new 200-kV field emission gun analytical microscope and an advanced analytical scanning electron microscope were installed; they are now in the final stages of testing and evaluation. The New Initiative project funded in FY 1993 involves the study of atomistic mechanisms at interfaces with Z-contrast direct atomic imaging and theoretical simulations. A major ORNL initiative related to the characterization efforts is the AMCL described in Sect. 4.

The study of radiation effects in materials is a major part of the KC02 01 program, especially with regard to the effects of neutron environments. This task has made major contributions to the understanding of mechanisms of reactor pressure vessel embrittlement, including recent research on the role of gamma embrittlement in HFIR and similar reactors. Research on neutron irradiation effects in pressure vessels also involves a significant collaboration with the Nuclear Regulatory Commission. Another important part of the radiation effects program is the investigation of radiation-induced degradation of the electrical properties of ceramics, work that is closely tied to fusion materials programs.

Solid State Physics—KC02 02 • The solid state physics program performs interdisciplinary research to advance the understanding of materials and materials-related

phenomena that underpin energy technologies. The emphasis is on fundamental problems of national scientific and technological importance in solid state theory, neutron and X-ray scattering, particle-surface interactions, thin films and interfaces, superconductivity, and the synthesis and processing of advanced materials. The program uses state-of-the-art materials research facilities at ORNL and develops advanced instrumentation and techniques for neutron scattering, synchrotron X-ray and photon research, ion beam and laser processing, and electron microscopy. Unique research facilities in neutron scattering, ion-solid interactions, and synchrotron X-ray research are made available to the scientific community through national user centers that attract more than 300 researchers each year. The program involves extensive interactions with other DOE programs, universities, government laboratories, and industry to broaden and strengthen the research and promote technology transfer.

The solid state theory program develops new theories to explain phenomena in energy-related materials and interacts closely with related experimental programs. Areas of interest include superconductivity, particle-solid interactions, surfaces and interfaces, phase transitions, neutron scattering theory, many-body theory, and magnetism. Both analytical theory and numerical simulations are performed. The program provides essential theoretical support for the experimental solid state program and involves close cooperation with the University of Tennessee (UT) through the ORNL-UT Distinguished Scientist Program and other collaborative arrangements.

The neutron scattering program uses the intense neutron beams at HFIR to investigate the structure and dynamics of condensed matter. Current areas of emphasis include excitations and flux lattices in high- T_c superconductors, magnetic excitations in materials, the structure and thermodynamics of polymer blends, phase behavior in colloidal materials, and high-resolution residual stress measurements. Extensive improvements to three neutron scattering instruments are nearly complete, and a significant upgrade to the powder diffractometer is under way. A new residual stress instrument is under construction as part of a cooperative program with DOE-EE (see Sect. 5.1.2.1). Completion of the spectrometer upgrades and the new residual stress instrument will give ORNL unsurpassed capabilities in thermal neutron scattering. More than 150 researchers used neutron scattering and small-angle scattering instruments at ORNL in FY 1994.

Increased emphasis is being placed on the synthesis and processing of advanced materials. Efforts in laser ablation molecular beam epitaxy have important implications for the growth of epitaxial superconductors and compound semiconductors. Commercial interest in ORNL's thin-film lithium battery technology remains high, and new materials and composite films for related applications are being synthesized. Fundamental research on glasses and ferroelectric materials is leading to new opportunities in photonic materials. The ion implantation program continues to make progress in the use of ion beams to tailor the surface properties of materials. More than 90 researchers used the ion beam facilities at the SMACRC in FY 1994, and new work on nanocrystalline and tribological thin films is under way. All of these activities involve extensive collaboration with industry, including CRADAs on photovoltaic materials, materials for thin-film batteries, thermoelectric materials, varistor materials, MgO crystal growth, plasma processing for submicron metallization, and ion beam processing (ceramic bearings, polarizing glasses, and implantation-based technologies for integrated circuits). Cooperative research is also under way with DOE-EE (SiC electronics, solid-state lithium batteries, and superconductor development) and with DOE national security programs (materials for sensors).

Continued development and application of advanced characterization techniques are essential to the solid state physics program. In addition to the neutron scattering instrumentation upgrade described above, major new capabilities in synchrotron X-ray research, electron microscopy, and scanning tunneling microscopy are emerging. ORNL is participating in the development of the UNI-CAT synchrotron beam line for the Advanced Photon Source. Support for adding a microprobe facility to UNI-CAT is being actively sought. ORNL is also a partner in the Howard University–University of Michigan–AT&T Bell Laboratories Collaborative Access Team (MHATT-CAT) and Complex Materials Consortium Collaborative Access Team (CMC-CAT) beam lines.

The 300-kV scanning transmission electron microscope is providing unprecedented resolution for research on a wide variety of materials, interfaces, and defect structures. The surface physics program, in cooperation with the ORNL-UT Distinguished Scientist Program, is using synchrotron X rays and photons, high-energy ion beams, scanning tunneling microscopy, and traditional electron spectroscopies to investigate the fundamental properties of metal and alloy surfaces.

Superconductivity research will emphasize critical currents, thin-film superconductivity, and materials synthesis and processing. Close interactions with DOE-EE and with industry will be maintained through the ORNL Superconductivity Partnerships Program.

Cooperative interactions with industry and with DOE technology programs continue to grow in all aspects of the solid state physics program. Industrial collaborations through CRADAs, the Superconductivity Partnerships Program, and the DOE Center of Excellence in Synthesis and Processing of Advanced Materials have become a significant part of the research effort. Active CRADAs number 13, and there are over 20 cooperative programs with DOE technology programs (including DOE-EE, the DOE-ER Office of Fusion Energy, and National Security programs) and the Nuclear Regulatory Commission. This outreach demonstrates the technological relevance of the program and helps bridge the gap between basic science and applications.

Materials Chemistry—KC02 03 • The Materials Chemistry Program focuses modern physicochemical methods on synthesis and characterization of advanced inorganic materials and organic polymer systems.

The inorganic materials synthesis program addresses materials with high-performance optoelectronic, magnetic, and mechanical properties and emphasizes nontraditional methods of synthesis to avoid the long processing times and high temperatures of traditional solid-state synthetic chemistry. This extends the use of advanced ceramic materials to applications that were not possible previously. Sol-gel and metal organic chemical vapor deposition (MOCVD) syntheses of multicomponent oxides lowers their crystallization temperatures and thus allows integration with standard silicon-based microelectronics or envisioned superconducting applications. Other synthetic techniques include spray and aerosol pyrolysis of aqueous precursor salt solutions, to produce thin films and fine-grained uniform powders, and reactive sputtering of metal alloys, to form novel nanocomposites of metals in an insulating or semiconducting matrix. A variety of characterization techniques are used to explore structure, composition, and property relationships.

Understanding the relationships among molecular structure, processing conditions, and performance properties of modern organic polymeric materials poses a unique challenge. Experimental techniques being applied include neutron and X-ray scattering for both semicrystalline fibers and largely amorphous polymers, neutron spectroscopy, thermal analysis, solid-state nuclear magnetic resonance (NMR) spectroscopy, scanning transmission

microscopy (STM), and atomic force microscopy. Computational advances are being made in molecular dynamics simulations and in applications of neural networks. Used in combination, these techniques are revealing often unexpected microstructural and dynamic features, particularly in the semirigid parts of polymer systems. A theory of polymer interactions is being tested for prediction of compatibility in nanoscale polymer blends; small-angle neutron scattering is the key experimental tool in this work. This research benefits from the presence of an ORNL-UT Distinguished Scientist.

Fundamental studies are conducted on the nucleation kinetics of ultrafine oxide powder synthesis and thermodynamics of oxide superconductors. The goal of the nucleation effort is to investigate the kinetics of molecular, macromolecular, and colloidal development during the synthesis of metal oxide particles by metal alkoxide hydrolysis and to develop theoretical nucleation and growth models to predict the dynamics of particle growth and morphology evolution. The purpose of the thermodynamic research is to measure and model chemical thermodynamic data basic to synthesis and processing of complex oxides used in engineering applications. The present focus is the (Y lanthanide)-Ba-Cu-O oxides, including high- T_c superconductors.

Chemical Sciences—KC03 • The Chemical Sciences Program supports HFIR; the Radiochemical Engineering Development Center (REDC); and a broad array of programs in atomic physics, chemical energy, separations and analysis, heavy element chemistry, and advanced battery technology.

Fundamental Interactions—KC03 01 • This program supports ORNL's experimental and theoretical atomic physics research and the operation of the EN Tandem Van de Graaff Accelerator. This program also supports two isotope production facilities, HFIR and REDC.

High Flux Isotope Reactor • Neutrons from HFIR are vital to many research projects in the materials sciences, chemical sciences, magnetic fusion, and biology programs at ORNL and for users and collaborators from many universities, laboratories, and industries. HFIR offers a unique combination of high flux, a mixed thermal/fission neutron spectrum, low irradiation temperatures, and flux tailoring. It supports neutron scattering experiments, isotope production, activation analysis, studies of material damage, and studies of advanced reactor concepts. HFIR operations are described in Sect. 5.1.6.1.

Radiochemical Engineering Development Center • R&D activities at the REDC involve the development and use of production processes and product forms for radioisotopes, predominantly the isotopes of transuranium elements. Transuranium-element isotopes produced at 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, biomedical applications, and waste isolation.

The DOE Transuranium Element Processing Program, the main program at the REDC, produces and distributes rare isotopes of the transuranium elements, including ^{248}Cm , ^{249}Bk , ^{249}Cf , ^{252}Cf , ^{253}Es , ^{254}Es , ^{255}Fm , and ^{257}Fm . The process used to produce these isotopes includes (1) fabrication of curium targets in the REDC hot cells, (2) target irradiation in HFIR, and (3) remote processing in REDC to separate and purify each of the heavy elements and to package the individual products for shipment. Researchers—located primarily at ORNL and the Los Alamos, Lawrence Livermore, Lawrence Berkeley, and Argonne national laboratories—use the heavy transuranium elements for R&D in nuclear, organic, and solid-state chemistry; nuclear physics; nuclear medicine; and other areas. The program is sponsored by the BES Division of Chemical Sciences.

REDC activities also provide, as a co-product of the Heavy Element Research Program, ^{252}Cf neutron sources, which can be used in neutron radiography, neutron activation analysis, and cancer therapy. The ^{252}Cf Industrial Sales/Loan Program, sponsored in part by the Office of Defense Programs (DOE-DP), is carried out to fabricate these neutron sources. Source capsules are fabricated in a variety of configurations and source sizes ranging from 1 μg to 50 mg of ^{252}Cf . Nearly 240 sources are on loan for uses in medical therapy or research, teaching or demonstration at universities, and industrial applications. About two-thirds of the sources in industrial applications are used by DOE offices or integrated contractors; the remainder are used by other agencies of the federal government. Bulk ^{252}Cf is also supplied to commercial neutron source fabricators. This work is done in the REDC Californium Facility in Building 7930. Other REDC projects and capabilities include a wide variety of special radioisotope preparations and "hot" experiments in support of existing and future DOE liquid waste pretreatment and management programs.

An educational capability exists at the REDC for B.S., M.S., and Ph.D. students in the areas of radiochemistry, accelerator target development, reactor target development, integral neutron cross-section measurement, and radiochemical processing. This capability could be used to enhance the training efforts of the Glenn T. Seaborg Institute for Transactinium Sciences.

Funding for the major programs currently carried out at REDC is ~\$14 million per year. Of this amount, DOE-ER provides ~55%; DOE-DP, ~43%. The Mark 42 Processing Program sponsored by DOE-DP is described in Sect. 5.1.3.1.

Atomic Physics • The atomic physics program at ORNL comprises 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. This program currently operates the EN Tandem Van de Graaff Accelerator, which provides a wide variety of light ions and multiply charged heavy ions at energies up to several million electron volts per nucleon. Members of the atomic physics group are also collaborating on a series of atomic studies involving ultrarelativistic heavy ions at the European Laboratory for Particle Physics (CERN). At the other end of the energy spectrum, experiments on cross sections for inelastic collisions of multicharged ions with neutral atoms and molecules are carried out at the lowest attainable energies; these experiments are conducted using the ORNL electron cyclotron resonance (ECR) ion source. Studies of collisions of multicharged ions with multicharged ions have been initiated, and a new program is proposed to study details of ion-surface interactions. These studies emphasize characterizing the energy and angular distribution of ejected electrons. The ECR source provides 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.

The atomic theory program studies atomic collisions over a wide range of energies using powerful new mathematical and computational methods. Particular attention is focused on complex systems, such as highly charged ions, that play a leading role in many branches of energy research. This program interacts strongly with the experimental atomic collision programs at ORNL and other laboratories. Many applications rely on access to supercomputers, notably the CRAYs at the National Energy Research Supercomputer Center and the massively parallel Intel Paragons at the ORNL Center for Computational Sciences. Much effort has been devoted to developing algorithms that efficiently use the features of these architectures. The Center for Computationally Intensive Physics, a collaboration involving

ORNL, UT, and Vanderbilt University, partially supports these activities. This center is part of a consortium that will use the Intel Paragon, which constitutes a unique resource for theoretical atomic physics. The center is interdisciplinary in scope, with collaborations in atomic, nuclear, and condensed matter physics.

Processes and Techniques—KC03 02 • Basic chemical research is performed to improve the fundamental understanding of methods for separating mixtures, issues underlying analytical techniques, the physical and chemical properties of actinides, advanced battery technology, and systems related to chemical conversions that underpin new or existing concepts of energy production and storage.

Chemical Energy • A unique array of complementary experimental and modeling techniques is applied to study thermodynamics of interactions and reactions in highly non-ideal aqueous solutions of electrolytes at high temperatures and pressures, especially near the critical point of water. The systems studied are selected for their fundamental significance to solution chemistry and critical phenomena 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. This basic chemistry program contributes fundamental chemical information to, and interacts synergistically with, a number of co-located, more applied programs concerned with energy production, environmental quality, and waste-related R&D.

Research in surface science-based 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. Several ultrahigh-vacuum surface structure approaches (including low-energy ion scattering techniques developed in this program) and surface reaction approaches are employed, including synchrotron-based spectroscopies to characterize molecular adsorbates.

Obtaining new molecular-level knowledge concerning the organic chemical structure and reactivity of coals is an area of continuing emphasis. Structural studies highlight the application of solid-state NMR techniques to chemically modified coals, with recent emphasis on ^{19}F NMR. Reactivity studies emphasize the use of surface-immobilized compounds to simulate diffusional restrictions during thermal and catalytic processing of coal. The information derived from these basic studies will contribute to the development of novel and environmentally sound processes for the use of coal as a source of liquid fuels, chemicals, and clean energy. The unique methods developed for coal research are being extended to related issues in the thermal processing of biomass.

Studies of the photochemical reactions and associated photophysics of aromatic molecules address atypical media such as very dilute aqueous solutions and sorbent solids. In addition to elucidating basic questions of photoreactivity in anisotropic environments, this work contributes to understanding the transformation of hazardous materials in natural settings exposed to sunlight. Research on photobiochemical reactions and enzyme kinetics is related to chemical energy.

Separations and Analysis • Laser-based optical spectroscopy and mass spectrometry are major ongoing areas of emphasis in analytical chemistry research. Mass spectrometry R&D is directed at a wide range of inorganic, organic, and biological materials. Current focus areas include novel ionization methods such as electrospray, matrix-assisted laser desorption, cluster impact secondary ionization, and glow discharge ionization; ion trap mass spectrometry and gas-phase ion chemistry; precise isotope ratio measurements; biological mass spectrometry; and secondary ion imaging of both inorganic and organic targets. Basic

research in laser-based optical spectroscopy places special emphasis on ultrasensitive (single-molecule) fluorescence detection, resonance ionization mass spectrometry, and nonlinear optical phenomena. A major recent initiative involves microinstrumentation. Performing chemical separations and manipulations on a microchip is the most mature of the approaches currently under development. Positron spectroscopy shows promise of providing new approaches to characterizing microstructural aspects of materials. This research currently makes use of the Oak Ridge Electron Linear Accelerator. A higher-intensity positron source has been designed for a research reactor such as HFIR.

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. Comprehensive studies encompass organic synthesis of new ligands, crystallographic and NMR elucidation of structures of extraction complexes, and equilibrium and thermodynamic analyses of performance and speciation. Current research emphasizes selectivity based on recognition of cations, anions, and/or ion pairs. Incorporation of complexing ability, charge-neutralizing ability, and organophilicity into single multifunctional extraction agents is stressed. Synergistic program interactions occur with more applied research on environmentally relevant separation problems.

Studies of transport phenomena in the presence of external fields in multiphase systems support advanced separations processes, and fundamental investigations of the interactions of solvents, solutes, and surfaces aid understanding of supercritical extraction and adsorption. Molecular-based studies of fluids and amorphous substances are performed on massively parallel supercomputers and validated by neutron scattering. New opportunities for molecular-based engineering and science are being developed.

Heavy Element Chemistry • Studies of the actinides emphasize the heaviest elements that are uniquely produced at the HFIR/REDC complex. The scientific goal is elucidation of the systematic trends in behavior of the characteristic 5f electrons as one progresses across 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 and clusters in high-temperature vapors, absorption and luminescence spectroscopic studies of solutions and solids, and magnetic and heavy fermion behavior at low temperatures. State-of-the-art relativistic quantum mechanics calculations are carried out to complement experimental studies. New emphases highlight the relevance of this basic science to current DOE technological issues in environmental restoration and waste isolation—for example, the structural issues involved in immobilizing actinide materials in glasses. Fundamental chemical studies are also performed on actinides and fission products by exploiting photochemistry and coordination chemistry for separations purposes from molten salts, aqueous solutions, and other media.

Advanced Battery Technology • Research being conducted will lead to the commercialization of the rechargeable thin-film lithium battery technology developed at ORNL for use in consumer electronics and medical devices. The significant issues that are addressed include developing a more reliable packaging method, conducting long-term life cycle experiments, measuring cell performance as a function of temperature and current density, and developing multicell batteries.

Engineering and Geosciences—KC04 • The major effort sponsored by the engineering component of the Engineering and Geosciences Program is the ORNL Center for

Engineering Systems Advanced Research (CESAR). CESAR's mission is to develop, demonstrate, evaluate, and provide quantitative performance analysis of methods, algorithms, and underlying theories necessary to design and build reliable sensor-based robots that can execute sets of tasks in unstructured workspaces. By combining long-range future-oriented R&D efforts with near-term, sustained technology transfer to U.S. industry and with graduate student education, CESAR strives to enhance U.S. scientific and technological capabilities in strategic areas vital to energy independence, national security, and global competitiveness. During the planning period, we will focus on the effective use of multiple cooperating agents, on problem areas associated with advanced manufacturing systems, and on enhancing collaborations with industry.

We characterize intelligent machines as systems that integrate perception, reasoning, and action to perform tasks under circumstances that are insufficiently known in advance and dynamically changing during task performance. Perception, reasoning, and action, as well as the integration of these modules into working systems, present challenging issues for interdisciplinary basic research. We have investigated, and continue to investigate, a wide variety of such issues in the areas of cooperating agents, combined mobility and manipulation, intelligent multisensory systems, and empirical estimation and machine learning.

In order to validate our research on actual robot platforms, we invest part of CESAR's resources in the development or purchase of an evolving series of mobile robot prototypes. The CESAR facilities include a state-of-the-art high-performance computing environment; numerous sensor systems, including multispectral vision sensors and laser range cameras; robot manipulators; and several mobile robots, some custom-built at ORNL and others commercially available (including a Remotec Andros Mark VI robot, a TRC Labmate, and a Robotics Research Arm) but customized at CESAR with sensors and computer control.

The DOE BES investment is leveraged and augmented by support from a number of sponsors that target various applications of robotics and intelligent systems. Within DOE, the Advanced Computing Technology Initiative program funds basic and applied research to develop novel computational methods for three-dimensional seismic analysis; the Office of Health and Environmental Research supports informatics and computational biology R&D that focuses on pattern recognition, database design and management, and data analysis and interpretation for genome-related applications; and the Robotics Technology Development Program of the Office of Environmental Management (DOE-EM) has been leveraging CESAR expertise and facilities in intelligent sensor systems, sensor-based mobile robots, and software architectures for robotics applications. CESAR expertise is also applied to the DOE-DP Technologies Enabling Agile Manufacturing (TEAM) project, focusing on virtual manufacturing for sheet metal forming. Other sponsors include the Department of Defense and the National Highway Transportation Safety Administration. The Office of Naval Research provides support for a multi-institutional Center for Neural Engineering. Tennessee State University (TSU), a historically black institution in Nashville, is the lead organization for this center, which also involves ORNL/CESAR, Meharry Medical School in Nashville, and Accurate Automation Technologies, a high-technology company in Chattanooga, Tennessee. The center uses the special CESAR facilities in robotics and intelligent systems to provide research and educational experiences to faculty and graduate students from the consortium participants.

CESAR R&D activities continue to yield results in the technology transfer arena. Contacts with industry collaborators are leading to cooperative R&D agreements (CRADAs). Significant liaisons, transfer of research results, and interactions with applied programs

include work with the DOE-EM robotics program, the Oak Ridge Centers for Manufacturing Technologies, and the Oak Ridge Transportation Technology Center. The Alliance for the Advancement of Robotics Technology, discussed in Sect. 5.1.7.3, will ease access to CESAR expertise for industry, universities, and other federal agencies.

Geoscience research focuses on the fundamental geochemical processes that control matter and energy transport in the earth's crust. These efforts contribute directly to exploration for and exploitation of oil, gas, and geothermal energy deposits; to our understanding of the fate of anthropogenic inputs into the environment; and to the management and remediation of toxic and radioactive wastes. Unique facilities and capabilities are developed and used in studies of the thermochemical properties of gases in the system $\text{H}_2\text{O}-\text{CO}_2-\text{C}_x\text{H}_y-\text{H}_2-\text{N}_2$; the nature of fluid-rock-soil interactions as constrained by the distributions of the naturally occurring stable isotopes of H, C, N, O, and S in fluids and solids; the solubilities of natural and man-made materials in subsurface brines; the geochemical controls on elemental transport; the subsurface lifetimes of natural and synthetic organic compounds over wide ranges of temperature and pressure; and the effects of fluid-rock-soil interactions on elemental transport and fluid flow at the scale of pores and grain boundaries using advanced analytical approaches.

Advanced Energy Projects—KC05 • The Advanced Energy Projects (AEP) Division has provided moderate levels of support to exploratory research in materials and chemical sciences. The typical project duration is three years. Representative ORNL projects have included the use of electric-field-driven reactors to fabricate ceramic precursors and the investigation of enzyme hydrolysis mechanisms for energy-efficient waste management and bioprocessing of cellulose products (e.g., wastepaper). Throughout the fiscal year, innovative research projects are proposed for support through the AEP program.

Applied Mathematical Sciences—KC07 • The Applied Mathematical Sciences (AMS) subprogram, managed by the DOE Office of Scientific Computing, supports computational science and advanced computing at ORNL.

ORNL's Center for Computational Sciences (CCS) is one of two High-Performance Computing Research Centers established as part of DOE's contribution to the national High-Performance Computing and Communications (HPCC) Program. With the recent addition of an Intel Paragon XP/S 150, the CCS is now one of the foremost computing centers in the world. The XP/S 150 is the latest in a sequence of computers that includes an XP/S 5, an XP/S 14, and an XP/S 35 (in the designation XP/S n , n represents the nominal peak speed in billions of floating point operations per second, or gigaflops). The CCS also includes a Kendall Square Research KSR1-64 machine, providing a shared memory platform, and a 16-processor IBM SP-2 for ORNL users. The CCS is responsible for:

- Providing computing resources to Grand Challenge groups in groundwater transport and remediation, materials simulation, global change [as represented by the Computer Hardware, Advanced Mathematics, and Model Physics (CHAMMP) program], quantum chromodynamics, computational biology, computational chemistry, the Numerical Tokamak Project, and the Quantum Structure of Matter group, as well as to users of the National Energy Research Supercomputer Center (NERSC).
- Providing a computing center capable of meeting program requirements, using massively parallel processing (MPP) computers and including data storage and access and networking systems consistent with the computing power of the CCS.
- Evaluating developing computer systems, procedures, and architectures.

- Developing software tools and computational techniques for high-performance parallel computing.
- Providing visualization opportunities and capabilities for CCS users.
- Developing computationally oriented collaborative projects with industry through the Computational Center for Industrial Innovation (CCII), a DOE national user facility.
- Developing and providing advanced networking, within the computing environment and to the outside world.

R&D programs in the CCS are focused on extension of user capabilities, the Evaluation of Early Systems (EES) Project, networking, and software development.

Emphases in extending user capabilities include state-of-the-art data storage and access systems, the development and implementation of innovative job scheduling systems, improvement in input/output (I/O) capabilities, additional computer languages, and more effective software algorithms exploiting Paragon features.

Storage and backup requirements for the CCS computers are demanding and will grow as computing power and user sophistication in parallel systems increase. The CCS and the Atmospheric Radiation Measurement (ARM) Program are developing a multiple-terabyte, high-performance file storage system that will house a complete data archive for the ARM Program (see Sect. 5.1.6.2) and meet the data archival needs of the CCS (projected at 15 terabytes in FY 1996 and increasing rapidly thereafter). The cost of the archive is shared between the ARM project and the CCS, based on the storage requirements of each. Capital requirements include devices that can (1) perform system backups effectively and reasonably quickly and (2) offload large files from the Paragon systems to a backup tape device.

CCS scientists have brought the National Storage Laboratory's UniTree storage system software into such effective operation that it is now our basic system. Initial experiments with the next-generation High Performance Storage System (HPSS), a network-centered parallel system, are now in progress.

The EES Project investigates new and experimental computer systems, focusing on innovative hardware and software features, to evaluate their suitability for Grand Challenge applications and provide feedback to machine architects, systems software designers, and application programmers. With the ORNL Computer Science and Mathematics Division, the CCS is concentrating in three areas:

- computing with emphasis on the performance and capabilities of the next generation of hardware for distributed computing;
- computing with emphasis on features that need to be better exploited so as to optimize the effectiveness of multiple-processor-node systems; and
- networking—particularly, effective highest performance computing, by linking high-performance MPP systems at separate sites and pressing to achieve asynchronous transfer mode (ATM) performance levels.

The EES Project includes a laboratory for exploring innovations in networking that will move us into the gigabit-per-second region and beyond. Because first-quality networking is the key to many aspects of our computing and communications future, we also emphasize the importance of the availability of "operating" networks for the CCS and for Grand Challenge users throughout the nation.

The ORNL Computer Science and Mathematics Division and the CCS are now working with Sandia National Laboratories (SNL) to set up an experimental, high-speed network between ORNL and SNL, with the aim of creating a heterogeneous, distributed

supercomputing system, made up of the largest Intel Paragons at both locations. We are pursuing and contemplating additional important networking experiments and strategies.

Software research programs supported by the CCS include atmospheric science, materials processing, computational fluid dynamics, molecular dynamics, groundwater remediation, and engineering design. Additional research, in both algorithms and application codes, is carried out in collaboration with scientists supported through the AMS basic research program and through the Partnership in Computational Science (PICS) Consortium. Current PICS members, in addition to ORNL, are DOE's Ames Laboratory, Brookhaven National Laboratory, and the Savannah River Site; the State University of New York at Stony Brook; the University of South Carolina; the University of Tennessee at Knoxville; Rice University; and Texas A&M University.

Grand Challenge research is supported in the CCS as part of the national HPCC Program. The groundwater modeling Grand Challenge, a part of PICS, is an extensive, multi-institution effort to develop a sophisticated flow and transport code incorporating chemical and biological phenomena. Algorithms developed through AMS basic research have greatly improved the performance of groundwater codes. The Grand Challenge in first-principles simulation of materials properties requires the use of highly sophisticated numerical techniques and enormous computing power to provide solutions to problems with sufficient numbers of atoms to simulate realistic conditions. Recently, quasiminimal residual (QMR) algorithms developed in the AMS basic research program were incorporated into the materials Grand Challenge codes, reducing the complexity from cubic to linear and enabling computations involving larger cluster sizes than were previously possible. The CHAMMP program, a DOE initiative in atmospheric and climate modeling, has recently achieved substantial progress and significantly higher resolution through hardware and software improvements, generated in the CCS and in the AMS basic research program, that span numerical methods, software tools, software engineering, statistical analyses, data storage, and visualization.

Industrial participation is a central feature of the HPCC Program and the CCS. Intel participates in the CCS through a CRADA that supports the full-time presence of three parallel systems engineers. Broad efforts, particularly in the ORNL Metals and Ceramics Division, have led to a wide range of cooperative projects with industry. The CCII, a DOE Industrial User Center, is the ORNL focal point for cooperative computational projects, with a charter that includes opportunities for extended-term, large-scale cooperative projects as well as initiation forays with organizations exploring new territory. A leading-edge visualization environment will be a key component of the CCII.

To maintain the forefront computing character expected of the CCS, we have carefully assessed the directions of supercomputing and have proposed or will propose to DOE the following actions:

- purchasing the Paragon XP/S 14 to maintain the highly effective hierarchical computing environment that we now have in place;
- immediately enhancing the I/O capabilities of the Paragons; and
- substantially expanding the software development activities, including a new thrust in seamless computing.

In addition, we will propose to DOE the enhancement of our computing power (roughly 200 gigaflops at present) to beyond 800 gigaflops in late FY 1997. Discussions concerning the hardware to accomplish this transition are in progress.

The basic AMS Program supports research in parallel processing algorithms; tools to facilitate the use of parallel and distributed computing systems; and the development of

applied mathematical, statistical, and computational methods for analyses of physical processes. These research activities are supported by an Advanced Visualization Research Center that maintains state-of-the-art visualization capability for scientific research collaborations and exploring enabling technologies. The resources of the CCS are used, as appropriate, to accomplish the research objectives of the AMS Program.

Notable achievements of the AMS basic research program include state-of-the-art sparse direct solvers, iterative techniques for solving differential-algebraic equations (DAEs), and software enabling technologies for concurrent computers, including software templates. The sparse direct solvers enable large-scale linear programming problems to be solved much more efficiently. The sparse matrix codes have been adopted in sparse eigenvalue computations in large-scale modeling of structural dynamics. The DAE work enables constraints such as conservation laws to be enforced, leading to more accurate simulations in several important applications, including the groundwater remediation Grand Challenge problem. Development and participation in enabling technologies have provided a meaningful context for mathematical software, including the creation of community standards such as BLAS, LAPACK, ScaLAPACK, PVM, and MPI. These standards are a prerequisite for the development of a concurrent software industry, which will lead to more widespread use of concurrent computers. In addition, the templates work plays a valuable role in teaching state-of-the-art numerical and parallel programming techniques to users.

Research will continue in the following areas: computational techniques and tools for solving Grand Challenge problems, heterogeneous distributed computing, algorithms and software for advanced computer architectures, performance characterization and evaluation of parallel computers and programs, and mathematical modeling of environmental and engineering problems and their numerical solution on parallel computers. Specific emphasis is placed on sparse and basic matrix computations, data and information analysis, design and analysis of computational experiments, and the analysis and numerical solution of partial differential equations. Areas of increasing emphasis include high-speed communication and networking, multimedia collaboration and reports, large-scale data and information analysis and visualization, data storage, computational steering, application parallelization, electronic commerce, and information databases. 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.

ORNL's strategic plan for computing is summarized in Sect. 7.2.

Energy Research Analyses—KD

ORNL provides support to DOE-ER in technical and economic assessments of alternative energy sources for selected sectors of the U.S. economy. Areas for peer review assessments of DOE programs include fossil energy, structural biology, and photovoltaics. The funding level varies according to the specific needs of DOE but is expected to remain relatively stable. Future technical and analytic support for assessments will be provided as requested. ORNL anticipates providing support for analysis of global climate change issues and new analyses in support of the National Acid Precipitation Assessment Program.

Advanced Neutron Source—KE

The President's budget for FY 1996 did not request funds for the Advanced Neutron Source (ANS). Thus, the ANS project at ORNL was terminated at the end of FY 1995.

Some of the capabilities for which the ANS was being developed can be met by a high-power spallation neutron source. DOE has requested funds for R&D and a conceptual design for such a neutron source and has designated ORNL as the preferred alternative site. Support for the R&D and conceptual design of the Oak Ridge Spallation Neutron Source, described in Sect. 4.1, is being provided through the Basic Energy Sciences Program (KC).

Multiprogram Energy Laboratories Facilities Support—KG

The DOE Multiprogram Energy Laboratories Facilities Support (MEL-FS) program provides funding for general-purpose, line-item construction projects at ORNL. General-purpose facilities relate to many programs and may include offices, laboratories, and shop buildings that house administrative and Laboratory-wide support functions; utility systems; and roads. Line-item construction projects are those with a total estimated cost of \$2 million or more. Within the MEL-FS program, the Inactive and Surplus Facilities Program (KG03) provides funds for removal of facilities with little radiological or chemical contamination. The MEL-FS program also supports ORNL's life cycle asset management activities, which are described in Sect. 6.

ORNL has a large number of facilities for which corrective construction projects are proposed. Data on site and facilities are presented in Figs. A.1–A.8 and Tables A.1–A.3 in the Appendix.

Biological and Environmental Research—KP

Goals of the Biological and Environmental Research Program are to (1) 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) map and sequence mammalian genomes; (3) contribute to DOE's Nuclear Medicine Program and other beneficial applications programs; and (4) transfer research findings and technological developments to the private sector. Research areas in biology include mammalian genetics, molecular genetics, protein engineering, cell biology, carcinogenesis, macromolecular structure, mutagenesis, and risk assessment. Environmental science research covers biogeochemistry, environmental biotechnology, global environmental chemistry, ecosystem studies, geosciences, hydrology, and environmental assessment. Health sciences research encompasses human health analysis, epidemiology, health assessments, radiation and chemical physics, nuclear medicine, and instrumentation development for sensitive detection and monitoring of chemicals. Two unique user facilities contribute to the ORNL Biological and Environmental Research Program: the Oak Ridge National Environmental Research Park and the Bioprocessing Research and Development Center. Users of these facilities include staff members from national laboratories and industry and students and faculty members from universities. Construction of the Center for Biological Sciences, described in Sect. 4.2, would enhance all of these activities.

The ORNL Biological and Environmental Research program is one of the broadest multidisciplinary life sciences research programs in the nation and covers a diverse range of

basic and applied studies. During this planning cycle, this program is expected to experience growth in several areas, including global change research, protein engineering, human genome research, and basic sciences supporting environmental engineering programs and bioremediation.

The ORNL Center for Biotechnology, described in Sect. 5.1.7.1, provides a coordinated focus for the Laboratory's extensive activities in bioscience and biotechnology. An initiative in computational biosciences, cutting across all elements of the ORNL program, is proposed.

Initiative

Computational Biosciences

Rapid advances in computer technology and computational sciences are having a major impact on the biological sciences. The integration of the tools of computational science into both the practice and the communication of the biological and ecological sciences is revolutionizing our understanding of the biological world. Within the next few decades, we may well be able not only to predict the three-dimensional structure of a protein from the DNA sequence of its gene, but also to make reasonable inferences about its function in the organism from which it was isolated. Increasingly sophisticated models of the local, regional, and global environments will allow us to more accurately predict the impact of human actions on the biosphere. Computational bioscience focuses on the application of high-performance computing technology to modeling, analyzing, and displaying the underlying behavior and physical principles of biological and ecological systems.

Computational areas with immediate biological impact include data access, analysis, and visualization tools; federated databases; modeling and simulation of complex systems; pattern recognition; image analysis; virtual reality; artificial intelligence; and high-performance computing facilities and software tools and environments in support of biosciences applications. Bioscience areas being affected by computational sciences include biological systems analysis and modeling (at molecular,

cellular, and organism levels), structural biology, protein engineering, molecular dynamics, drug design, genome analysis, biokinetics, and environmental modeling (climate, ecosystem, population).

ORNL and DOE have a variety of resources that can be applied to computational biosciences. The technical expertise, diverse capabilities, and high-performance computing facilities at ORNL are key resources for this initiative.

An infrastructure for computational biology has been established through a project funded by the Laboratory Directed R&D Fund. One focus area—prediction of protein folds using high-performance computing tools—involves a systematic and comprehensive evaluation of existing empirical energy calculation methods based on crystallographic structures in the database, as well as high-speed methods for evaluating potential protein folds using structural information (inverse folding) and forward folding using genetic algorithms. Both of these are being implemented on massively parallel computers such as the Intel Paragon in the ORNL Center for Computational Sciences.

New and more simplified representations of amino acid side chains have been developed; these representations greatly improve the efficiency of energy calculations for potential protein fold evaluation. Progress in structure-based prediction of protein folds will have a significant positive impact on the human genome project, on

structural biology, and on computational Grand Challenges in rational protein design and drug design, catalysis, and biotechnology.

A number of other technical focus areas with potential long-term impact are being developed. These include inter-operable analysis and database systems, an Internet server system for protein structural

classification, internal biokinetic dosimetry and anatomical modeling, individual-based population modeling, and medical applications for high-performance computing. Funding is being sought from DOE's Office of Health and Environmental Research and from other sponsors. Table 5.2 provides a summary of the anticipated funding.

Table 5.2
Anticipated funding by fiscal year for the Computational Biosciences initiative
(\$ in millions—BA)

	1996	1997	1998	1999	2000	2001
Operating	0.8	1.0	1.2	1.8	2.0	2.0
Capital	0.1	0.2	0.2	0.2	0.2	0.2

Analytical Technology—Measurement Science—KP01 • The Chemical and Analytical Sciences Division is developing and applying highly sensitive and selective techniques based on mass spectrometry for the structural characterization of selected biomolecules at the cellular or subcellular level. We are currently extending the applicability of mass spectrometry to biopolymers of higher molecular weights using recent advances in ionization techniques, including both matrix-assisted laser desorption/ionization (MALDI) and electrospray (ES). The ability to identify selected species from a cell, such as modified segments of DNA, peptides, and carbohydrates, allows the development of an understanding of the mechanisms for formation and the effects of these modifications, as well as the development of methods for the detection of these compounds as markers of human dosimetry. An important part of this research includes collaboration with biological scientists at ORNL and in other academic, industrial, and government laboratories.

The research activities of the Advanced Monitoring Technology Program are aimed at developing novel and improved monitoring technologies to measure, in subsurface environments, chemical pollutants associated with energy-related technologies. The research focus is on the development of portable instruments, cost-effective screening tools, and advanced biochemical sensing technologies for key pollutants and related biological compounds in complex samples where current techniques are unavailable or inadequate.

Environmental Research—KP02 • The goal of the environmental research program is to increase our understanding of the transport, transformation, and effects of energy-related activities on 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, we emphasize linkages among the atmosphere, the terrestrial biosphere, and freshwater systems.

Environmental Biogeochemistry • The ORNL atmospheric research project concentrates on quantifying several aspects of atmosphere/biosphere exchange that are critical in understanding and predicting the effects of global change. These include wet and dry removal processes and surface emission rates of both natural and pollutant constituents important to

tropospheric chemistry and biogeochemical cycling. Major emphasis is placed on determining the interactions of these materials with forest canopies, particularly in complex terrain. Projects include testing and application of throughfall methods for quantifying terrain and canopy controls on deposition in mountain forests and developing and testing methods and models of mercury vapor interactions with land and water surfaces. This work supports DOE tasks in the areas of dry deposition, precipitation scavenging, deposition modeling, landscape scaling, biogenic emissions, and biogeochemical cycles.

Transport studies involve the measurement of naturally occurring radionuclides (^3H , ^7Be , ^{35}S , and ^{210}Pb), anthropogenic radionuclides (^{137}Cs , ^{239}Pu , and ^{240}Pu), and stable isotopes (^2H , ^{13}C , ^{15}N , and ^{18}O) to trace and quantify the dispersal and fate of energy-related materials, as well as fixed carbon, in watershed, estuarine, and ocean-margin systems. The watershed research is focused on identifying groundwater and surface water sources and on quantifying the extent to which atmospherically derived substances (e.g., sulfur and lead) biogeochemically interact with drainage-basin soils and vegetation during runoff or snow-melt. The marine research focuses on using biogeochemical tracers to quantify the exchange of materials between land and sea, between continental shelf and slope, and between sediments and water column.

Planning and scientific exchange between two institutes of the Russian Academy of Sciences—the Institute of Energy Problems and Chemical Physics and the Institute of Oceanology—and ORNL are aimed at developing a joint research program to investigate biological and biogeochemical effects of increased ultraviolet radiation on marine ecosystems. ORNL-led studies within the program framework include assays for DNA damage in phytoplankton that can be attributed directly to ultraviolet B (UV-B) radiation as well as changes in biogeochemical cycling as traced using radioisotopic tracers and stable isotopes. The program takes advantage of the complementary and unique skills of each organization involved. This research is important 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, for determining the potential effects of these substances on terrestrial and marine ecosystems, and for evaluating rates of transfer and cycling of carbon between various reservoirs that may be influenced by global change.

Research for DOE's Office of Health and Environmental Research (OHER) on the effects of UV-B radiation emphasizes the ecological effects on freshwater, marine, and terrestrial organisms. All three areas include DNA analysis of sensitive developmental stages and/or potentially vulnerable species. The freshwater task focuses on potential UV-B effects on shallow-water benthic food webs. The marine task focuses on potential UV-B effects on early developmental stages of herring and sea urchins, species that spawn during periods of ozone column thinning. The freshwater and marine tasks will employ DNA molecular dosimeters to detect and quantify UV-B radiation in situ. The terrestrial task focuses on potential UV-B effects on forest tree pollen, testing the hypothesis that genetic damage from rising UV-B levels will be strongly influenced by reproductive habit (wind-pollinated vs insect-pollinated) and geographic origin. The National Science Foundation and the Office of Naval Research also provide support for our ocean programs.

Ecosystem Function and Response • Research for OHER on ecosystem function and response in ORNL's Environmental Sciences Division focuses on the Program for Ecosystem Research (PER). This program provides fundamental insights into how ecosystems and organisms respond to environmental variations and changes, how these responses are

controlled, and how they can be integrated across organizational levels. PER studies will determine the fundamental processes and properties of ecosystems that are critical to the prediction of ecosystem adjustments to perturbations such as global climate change.

The Walker Branch Watershed is a central research facility for the PER, with ongoing investigations of watershed-scale biogeochemical cycling, atmospheric deposition inputs, atmosphere/canopy interactions, biogenic emission and trace gas flux measurements, mechanisms of physiological response of vegetation to stress, nutrient cycling, subsurface hydrologic transport, and effects of nutrient cycling processes in streams. The goals of the research conducted at the Walker Branch Watershed facility directly address the objectives of the PER by providing a mechanistic understanding of the key processes that regulate ecosystem adjustment.

Results of these process studies provide input to watershed-scale models of ecosystem response and also stimulate new hypotheses of system response that are amenable to testing. Developing a fundamental understanding of the spatial and temporal variations in processes that regulate the storage, transformation, and transport of critical ecosystem components such as carbon, nitrogen, and phosphorus is a key objective of this work. Work is progressing on a major experiment to investigate ecosystem response to long-term shifts in the moisture balance of this deciduous forest watershed. Results of this experiment will significantly expand knowledge of the potential effects of drought induced by climate change on critical ecosystem processes related to growth, nutrient cycling, and species competition. In addition to the watershed-scale research, other ongoing work in support of the PER includes studies of climate warming effects on critical belowground processes, soil carbon turnover, and implications of warming on the processes regulating forest succession.

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

- integration and synthesis of existing data across parks, including site characterization data collected as part of the Environmental Restoration Program;
- coordination of activities among parks;
- on-site data management and data organization (including establishment of computer databases of historical data) and coordination with the Oak Ridge Environmental Information System (see Sect. 5.1.6.2) and DOE waste management activities;
- activities promoting the parks as a coordinated network of cooperating research sites; and
- providing an extant array of experimental sites, the extensive background data, and mechanistic understanding that provide an ecological baseline against which to evaluate ecosystem adjustment to changing environmental conditions.

The park is a component of the Southern Appalachia Man and Biosphere Reserve. Park activity provides regional leadership on biodiversity, climate change, and environmental education. The park currently receives no funding from DOE, and park activities have been severely limited in recent years. Funding for management of the natural resources of the Oak Ridge Reservation and the park is being sought through overhead funding at DOE facilities on the reservation (ORNL, the Oak Ridge Y-12 Plant, and the Oak Ridge K-25 Site).

Activities conducted at but not funded by the park include administration of wildlife management (deer hunts, turkey and osprey restoration, and pest management), wetlands surveys, herbarium development, and rare plant surveys and management.

Future activities and responsibilities of the Research Park are being designed to support, subject to available funding, DOE's intent to implement an "Ecosystem-Based

Management Plan.” Such activities are essential to the Department’s ecosystem-based management initiatives, which address the ecological concerns of management via the network of parks. ORNL will continue planning for ecosystem-based management, using the research park as the centerpiece for ecological input. As an example, the Oak Ridge park is serving as a test site for development of a risk assessment framework for management of DOE and Department of Defense lands, supported by a five-year project beginning in FY 1994 and funded by the multiagency Strategic Environmental Research and Development Program (SERDP).

Theoretical Ecology • Research will focus on global change and other DOE needs and the theory to integrate biological processes (e.g., biodiversity and structural organization of ecosystems) across different scales. The development of spatially explicit decision models for land management funded by SERDP will be used to assess the impact of DOE activities on natural and cultural resources. The research will build on and require further development of ORNL’s expertise in the theory of risk assessment, spatial analysis, and dealing with information at different spatial and temporal scales. Theoretical approaches that are being explored will extend the results of experimental studies being performed as part of the PER to broader spatial and temporal scales and to a wider variety of conditions.

Subsurface Science Program • The DOE Subsurface Science Program (SSP) emphasizes the integration of microbiology, geology, hydrology, and geochemistry to understand natural processes that control element mobility in the subsurface. Increasing our limited knowledge in this area will lead to an improved ability to characterize, monitor, and treat DOE sites contaminated with radionuclides, organics, and metals.

ORNL staff perform research in support of several portions of the SSP. Extensive research has been conducted on the transport and transformations of cobalt–ethylene diamine triacetic acid (EDTA) complexes in heterogeneous subsurface systems. Current efforts include quantifying the role of microbial reactions coupled to the inorganic reactions. This work will lead to an understanding that will directly benefit DOE sites where ^{60}Co contamination is prevalent.

Investigations of microbial heterogeneity are being conducted at field locations in the eastern United States. These investigations involve sampling subsurface geologic formations, groundwaters, and in situ microbial populations to discover what parameters control the distribution of microbial populations in the subsurface. This work has significant implications not only for understanding the evolution of natural microbial populations in the subsurface, but also for determining how native microbial communities might be used for in situ bioremediation. Understanding the heterogeneity is critical to evaluating whether the communities can be effective in the areas where contaminants are present.

Related investigations of how bacteria are transported in the subsurface are being conducted with other SSP investigators. Deep subsurface microbial sampling is conducted to attempt to resolve hypotheses related to the origin of bacteria that exist in the deep subsurface (thousands of feet deep). Unusual bacteria have been discovered and are now being studied to determine the unique metabolic characteristics that allow them to survive in the deep subsurface. Through these investigations, bacteria with capabilities to perform novel remediation or manufacturing processes may be developed.

Research is being conducted to understand how colloids may be generated in the subsurface, both naturally and under stressed conditions that may be found during in situ remediation. Colloids can be used to both mobilize and immobilize contaminants. Therefore, understanding the processes that control the formation and transport of colloids and any

attached contaminants is critical in assessing the risk that may be present at a site before, during, and after treatment.

Environmental Management R&D—Basic Science • Work is under way to address the following broad objectives, which are interrelated and of significant priority in the following order:

- implementing a consistent approach in assessing (1) the impact of remediation on human and environmental health and (2) the health and environmental risks associated with historical, current, and planned waste management and disposal operations;
- gaining an understanding of the hydrogeological, biological, and geochemical factors that control the movement and chemical transformations of radioactive, hazardous, and mixed wastes in subsurface and surface water systems;
- developing methods for the accurate prediction of contaminant movement in the environment;
- developing new remediation technologies (physical, chemical, and biological) for environmental restoration; and
- using methodologies in performance assessments and postremediation monitoring.

These broad objectives demand the integration of a variety of technical disciplines. Analysis capabilities, including those related to geochemistry and hydrology as well as to risk analysis, must be developed, and fundamental databases are needed to support the analytical models. The relationships between wastes of different types and a variety of natural processes must be studied. We emphasize microbial transformations that can be used in remediation and other biological parameters that can serve as indicators for risk and performance assessment. This work will require enhanced computational capability and the use of decision analysis methods that incorporate risks, costs, and benefits as a means for aiding restoration decisions. Basic research issues of importance to the waste R&D effort will change as technologies develop and as new problems are encountered.

Research on genetically engineered microorganisms (GEMs) for in situ remediation of biocontaminants requires that appropriate regulatory permits [e.g., Resource Conservation and Recovery Act (RCRA), Toxic Substances Control Act (TSCA)] be obtained before such organisms can be released into the environment. For a GEMs project now in progress, the TSCA application was submitted by the University of Tennessee, a collaborator on the project. Comments on the initial TSCA application were addressed, and the final application is now in review. The RCRA statute will not apply to the GEMs project as now described.

Health Effects and General Life Sciences—KP03, KP04 • Common themes within these activities are interactions of animals, cells, and molecules with their environments. In the analytical technology area, the 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 both theoretically and experimentally. Efforts encompass interactions at the atomic, molecular, and macroscopic levels in solids, liquids, and gases; on surfaces; and at solid-liquid interfaces. Strong emphasis is also placed on developing 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 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 in health and general life sciences also include mammalian genetics, protein engineering, and molecular and cellular biology.

Mammalian Genetics • A large mouse colony and staff expertise in genetics, molecular biology, cytogenetics, pathology, reproduction, and development provide the resources for coordinated studies that use mutations of all kinds to investigate genome structure/function correlations, mechanisms of mutagenesis, and the action of genes in development. Hundreds of mutations induced by radiation and chemicals include valuable complexes of overlapping deletions and other rearrangements. In addition, insertional mutagenesis (by transgenic mouse technology) provides molecular tags for access to and cloning of genes, and targeted mutagenesis (by embryonic stem-cell technology) enhances the means for exploring gene function.

Molecular and advanced cytogenetic techniques are used for analyzing the nature of agent-induced and insertional mutations, advancing the understanding of mechanisms of mutagenesis. In addition, the program is a national resource for studying genetic risk from environmental mutagens and for determining the sensitivities and biological properties of diverse types of reproductive cells.

The mouse genetics colony, which propagates stocks of hundreds of mutants that have arisen over decades of mutagenesis studies, is an international resource that is being exploited through both outreach and in-house research and is becoming increasingly important for attempts to understand gene function. Over the past 4 years alone, mutant stocks have been supplied to over 75 laboratories throughout the world for collaborative or independent investigations. Furthermore, the numerous mutations centered on each of seven specific loci have been characterized into deletion complexes that constitute invaluable resources for intensive regional genome mapping.

The mouse genome is analyzed with the objectives of building bridges to the human genome and especially of finding functions for human genes that might otherwise be characterized only at the structural level. Through the use of recently developed methods for long-range physical mapping and cloning, detailed maps of selected regions of mouse-human homology are being developed, and the comparative maps are being refined by assigning human cDNA clones to positions on mouse chromosomes. Because neither mutation induction nor certain developmental studies are feasible in humans, the mouse provides an excellent model for exploring the *in vivo* functions of human genes. The pathology and developmental physiology of selected mouse mutants that provide models for human genetic disorders are investigated in depth. Recent examples are DNA-structure/function studies in stocks propagating mutations that cause congenital cleft palate, polycystic kidney disease, and an autoimmune disorder.

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

Protein Engineering • Protein engineering (site-directed mutagenesis) represents the use of recombinant DNA technology to alter the structure of proteins systematically by

replacement, addition, or deletion of amino acids in targeted regions. Since its recent inception, protein engineering has emerged as the most powerful tool for probing relationships between structure and function and has opened exciting new vistas for optimizing properties of proteins for medical, industrial, and agricultural applications.

In its breadth and integration of many activities in molecular genetics and biochemistry, ORNL's program in protein engineering is unique among DOE laboratories. Long-term efforts are focused on enzymes that are relevant to biomass yields and on polypeptide hormones that regulate cellular growth and differentiation.

Examples of the former are ribulose biphosphate carboxylase/oxygenase (Rubisco), which catalyzes photosynthetic CO₂ fixation; phosphoribulokinase (PRK), which catalyzes the formation of the CO₂ acceptor molecule; and thioredoxin (Td), a redox protein that modulates the in vivo activity of numerous enzymes. For Rubisco, two compelling reasons exist for carrying out site-directed mutagenesis: (1) despite the absolute dependence (direct for plants 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 CO₂ fixation) could be reduced, major increases in plant productivity might be achieved. PRK is of particular interest because of its ill-understood regulation by photon flux as mediated by Td. The pathway for sulphhydryl-disulfide exchange between Td and target enzymes is under investigation, as are specificity determinants of redox proteins.

Examples of the work on polypeptide hormones are human epidermal growth factor (EGF) and its specific cell-surface receptor, which when complexed with EGF mediates regulation of cell growth. Given the relevance of protein engineering to multiple missions of DOE and the proven track record of this program, expansion would be warranted if permitted by budgets.

Molecular and Cellular Biology • Several projects, designed to elucidate molecular aspects of structure and function that are involved in key cellular processes, also serve to support or interface with the other programs described here.

Analyses of satellite DNA sequences and their organization and function in the eukaryotic genome are being studied at different stages of development. Structure/function studies of mammalian chromatin serve to elucidate the functionality of chromosomal elements during cellular development. Molecular details of eukaryotic messenger RNA (mRNA) turnover and its orchestration by key enzymes are being unraveled. Structural biology includes crystallographic analyses of the nucleosome core particle and growth factors.

Research in molecular immunology emphasizes the role of cell-surface receptors in the development of carcinomas and the diagnosis and possible treatment of carcinomas by antibody-directed cell targeting. Initiation events that convert normal cells to potential cancer cells are often mediated by host factors. Ongoing studies of such factors influencing either progression of an initiated cell to a tumor or suppression of its cancer potential are therefore central to the understanding of carcinogenesis in general and radiation-induced cancer in particular.

Cryopreservation of embryos and sperm from disparate organisms is essential to the maintenance of the accelerating numbers of transgenic and other mutant lines. This is especially true in the mouse. Consequently, with strong encouragement from OHER, ORNL is investigating the fundamental factors that will permit the development of cryopreservation procedures for mouse sperm.

ORNL Genome Program • ORNL is strongly committed to the national effort to analyze the human genome. Comparisons of structure and function within related regions of

the mouse and human genomes and development of advanced sequencing and mapping techniques are two thrusts of the ORNL program. The mouse provides an excellent model system for exploring the in vivo functions of human genes for a number of reasons: extensive homologies exist between the genomes of humans and mice; genetic engineering procedures coupled with standard mutagenesis tools are available for experimentally manipulating the genome of a mouse; and many experimental studies that are not feasible in humans can be done in mice. Most important, mutations generated in mice provide powerful tools for the correlation of genome structure with function and will prove to be crucial in deciphering the biological information inherent in the emerging physical maps of the human genome.

DOE-OHER has funded a multiple-investigator project on mouse-human genome relationships that is proceeding as follows.

- Long-range physical mapping and cloning are being used to develop detailed maps of selected regions of mouse-human homology, including proximal mouse chromosome 7 (Mmu7) and related regions of human chromosome 19 (HSA19), in collaboration with the Human Genome Center at Lawrence Livermore National Laboratory.
- The existing mouse-human comparative genetic map is being refined and expanded by assigning conserved human DNA markers, especially cDNA clones, derived from HSA19 and other targeted human regions to specific mouse chromosomes.
- ORNL's capability in targeted mutagenesis is being used to determine the whole-organism function of mapped genes in humans and mice.
- The feasibility of inducing deletion complexes at specifically targeted sites throughout the genome, using rapid, cost-efficient ES-cell-based methods, is being studied.
- Intensive structure/function studies are being pursued in genomic regions for which deletion complexes have been generated.
- Molecularly tagged mutations are being created throughout the mouse genome by insertional mutagenesis, using both zygotic pronuclear microinjection and embryonic stem-cell techniques.
- Mutagenesis techniques are being used to create models of human genetic disorders.
- A national database for transgenic mouse mutants is being established.
- Artificial intelligence and neural network techniques are employed to identify important DNA sequence patterns.

New methods to increase the rate and accuracy of DNA sequencing and mapping are being developed at ORNL for analysis of mammalian genomes. These efforts include

- development of mass spectrometric methods for rapid analysis of DNA sequencing products;
- use of solid-state oligonucleotide arrays to analyze target DNA sequences by hybridization;
- application of scanning-probe microscopy for high-resolution physical mapping of DNA molecules;
- development of new DNA labels containing nonradioactive metal isotopes for detection by luminescence, mass spectrometry, or electrochemical techniques;
- development of sensitive optical techniques for quantitative detection of unlabeled DNA in hybridization arrays; and
- fabrication of devices for microscale purification and sequencing of DNA.

Unique computer-based sequence analysis methods for identification of biologically important regions in newly sequenced DNA are being developed, drawing on neural network, artificial intelligence, and parallel computational techniques. ORNL's GRAIL software (Gene

Recognition and Analysis Internet Link) rapidly and reliably locates gene components such as exons, introns, and gene control elements. Related software is used for the automated assembly of these components to describe whole genes. In addition to GRAIL's use in the mouse genome program, several hundred other laboratories access it via the Internet for analysis of important human disease genes.

The Human Genome Management Information System at ORNL (discussed in Sect. 5.1.6.2) provides the human genome programs of DOE and the National Institutes of Health (NIH) with a communication network throughout the international community that is engaged in human genome research.

Resources that support the ORNL Genome Program, at ORNL and in the local area, include

- a 250,000-mouse colony organized for genetic studies;
- a transgenic mouse facility;
- a program in targeted mutagenesis that uses embryonic stem-cell technology;
- a collection of several hundred stocks of mouse mutations, propagated by breeding or preserved as frozen embryos;
- the ORNL Center for Computational Sciences;
- synthetic chemistry laboratories;
- laboratories for high-resolution mass spectrometry and resonance ionization spectrometry;
- a nucleic acids chemistry laboratory with oligonucleotide array synthesis capability;
- facilities for sensitive detection of labeled DNA fragments by mass spectrometry;
- analytical chemistry facilities that include high-resolution Fourier transform (FT) mass spectrometry, FT nuclear magnetic resonance, FT infrared, and ultrasensitive laser luminescence capability; and
- facilities for sensitive detection by enhanced Raman, luminescence, and phosphorescence techniques.

Construction of the Center for Biological Sciences, described in Sect. 4.2, would extend and enhance these resources.

ORNL divisions interacting to develop this multifaceted program include Biology, Chemical and Analytical Sciences, Computing and Mathematical Sciences, Health Sciences Research, and Instrumentation and Controls.

Carbon Dioxide Research—KP05 • ORNL is a center of expertise in global environmental research. Activities include developing global biogeochemical models, implementing data and information systems, integrating social systems into science and technology, fostering the application of high-performance computing to atmospheric general circulation models (GCMs), conducting field and laboratory research on the effects of CO₂ on vegetation, conducting integrated assessments of the consequences of global change, and developing unique instrumentation packages for global applications. ORNL is also exploring appropriate science and technology needed to support sustainable development activities domestically and internationally. These activities and other research thrusts within other existing ORNL programs are the technical foundation for the ORNL Center for Global Environmental Studies (CGES), which involves staff members from many ORNL divisions as well as outside collaborators. The CGES is described in detail in Sect. 5.1.7.1.

The Carbon Dioxide Information Analysis Center (CDIAC) compiles, evaluates, and distributes information on CO₂, other greenhouse gases, and long-term climate changes, in support of the CO₂ research program. In the coming years, the Center's research activities

will focus on the areas of emphasis of DOE's Global Change Research Program (e.g., carbon emissions from fossil fuel combustion; carbon fluxes between the atmosphere, the oceans, and the terrestrial biosphere; long-term climate records). CDIAC will also focus on electronic distribution of its data and information products and on fully integrating its data management activities with the U.S. Global Change Data and Information System. CDIAC's scientific and technical information management activities are described in Sect. 5.1.6.2.

Computer Hardware, Advanced Mathematics, and Model Physics • The Computer Hardware, Advanced Mathematics, and Model Physics (CHAMMP) Program is directed toward the development of an advanced climate model that uses the hardware and software capabilities of massively parallel processing (MPP) computers and incorporates the best numerical approaches for atmospheric and oceanic dynamics, combined with the most accurate representation of cloud feedbacks, chemical processes, and terrestrial systems. In the near term, CHAMMP will achieve improved GCM performance by using MPP supercomputers such as those in the ORNL Center for Computational Sciences (CCS). ORNL scientists are working with staff members from Argonne National Laboratory and the National Center for Atmospheric Research to provide parallel implementations of the Community Climate Model and to improve key numerical algorithms for parallel computation. ORNL scientists are keenly interested in CHAMMP projects that will couple atmospheric, oceanic, and terrestrial models. With these models, new understanding of the CO₂ problem may be gained.

Carbon Dioxide Effects • In support of the DOE Terrestrial Carbon Program, researchers are investigating the potential for elevated concentrations of atmospheric CO₂ to ameliorate the adverse effects of climate warming on forest tree species. Tree seedlings are being grown in multiple temperature-controlled, open-top chambers in the Oak Ridge National Environmental Research Park. The effects of CO₂-temperature interactions on tree growth are being measured to explore the mechanisms of plant and ecosystem adjustment. A particular objective of this research is to describe the direct and secondary processes involved in carbon cycling and sequestration by forests. This research will lead to a more realistic assessment of the integrated responses of terrestrial ecosystems to global change.

Atmospheric Radiation Measurement • The Atmospheric Radiation Measurement (ARM) Program is a DOE initiative to aggressively monitor atmospheric phenomena that affect heat flux, with the objective of providing an experimental testbed for studying the effects of atmospheric phenomena, particularly cloud interactions, on long-wave radiative processes. This information will be used to improve the modeling of atmospheric and radiative processes, with the ultimate goal of improving GCMs. ORNL serves as the data center for all data generated by this program. Staff in the ORNL Environmental Sciences Division are developing the ARM archive facility to provide scientific data management for the project data, with support from the CCS. Also under development are methods to document and summarize the data and to provide user access tools. Documenting and summarizing the ARM data will be particularly critical because the ARM archive will be the primary point of contact for the general scientific community seeking data from the project. The ARM archive activity is described in more detail in Sect. 5.1.6.2.

Socioeconomic Studies • The objective of ORNL's socioeconomic studies is to lay the economic foundations for more complete and realistic integrated assessment models. At a more fundamental level, socioeconomic research activities provide a better understanding of the processes by which the economy may move to new technologies that address climate change.

Currently, research efforts are attempting to incorporate more sophisticated and complete economic components into integrated models to address global climate change. Research is focusing on economic productivity and the role of technological advances that would affect the level of uncontrolled greenhouse gas emission, the ability to mitigate emissions, and the ability to adapt to potential changes in climate. Evolutionary modeling methods are being applied to the problem of characterizing long-run technological change and technology adoption in energy-economic systems. Traditional approaches have been limited by their evaluation of long-term change and technology choice. Experimental economics is being used to evaluate different investment models, such as the irreversible investment approach, which suggests that when there is uncertainty, irretrievable sunk costs, and the ability to wait while gathering more information, investors will require premiums akin to option values before investing.

Integrated Assessment • Integrated assessment is a process in which the scientific, technical, social, environmental, and economic consequences of a decision are evaluated to provide the information and analyses needed by policy makers and other decision makers to arrive at informed decisions on science and technology. For any problem, integrated assessment should identify the policy alternatives; analyze the scientific, technical, social, environmental, and economic costs and benefits of each alternative; identify the major sources of uncertainty; and provide some measure of the consequences of a wrong decision.

ORNL has a unique breadth of scientific, engineering, environmental, economic, and social science expertise to address the broad range of issues that arise in performing an integrated assessment, as well as extensive experience in using interdisciplinary teams to address a wide range of issues, from the generic relicensing of all commercial nuclear power plants in the United States to evaluating the safety, environmental, and health initiatives supporting U.S. research operations in Antarctica. The objective of ORNL's integrated assessment activities is to develop and implement assessment methodologies for conducting comprehensive, interdisciplinary assessments of global climate change.

ORNL provides planning support to several parts of DOE by providing assessments and analyses of research opportunities. Other examples of ORNL's integrated assessment capabilities include the vertical integration of research results into assessment and policy analysis under the National Acid Precipitation Assessment Program.

ORNL is helping to focus the national integrated assessment programs by organizing and conducting a series of national and regional workshops that will identify national policy issues and the available frameworks and methodologies to address these issues. Approaches for regional ecological integrated assessments are also being developed through a separate series of workshops. A systems view is used in coordinating the interdisciplinary thrusts needed to fully understand the effects of global climate change on social systems and the environment. Reduced-form models that will combine appropriate social sciences with ecosystem theory are being explored, as are data availability and accessibility issues.

Medical Applications—KP06

Nuclear Medicine • The ORNL Nuclear Medicine Program focuses on the design and development of new tissue-specific radiopharmaceuticals for diagnostic and therapeutic applications in nuclear medicine. Key strengths of the program are radiopharmaceutical chemistry, animal evaluation, radiochemistry, development of radioisotope processing techniques, and radionuclide generator research. The High Flux Isotope Reactor (HFIR) represents an important resource for this program, and the development of radionuclide processing technology and generator research are major areas of productive work.

The molecular modeling of new tissue-specific radiopharmaceuticals is a major emphasis. The development of ^{123}I - and ^{18}F -labeled cerebral receptor binding agents is a key example. Certain molecular forms can measure changes in neurotransmission encountered in many neurological diseases. The goal is to measure, by means of external imaging techniques, changes in receptor density or activity that occur in various diseases. Agents under development include improved analogs that bind to the cholinergic-muscarinic receptors involved in dementias such as Alzheimer's disease and new analogs that bind to the serotonergic receptors that are involved in mood disorders.

In conjunction with the syntheses of these and other agents, new and improved radiolabeling techniques are being developed for radioiodination of molecules sensitive to the usual methods. A key example is the development of the $^{188}\text{W}/^{188}\text{Re}$ generator system, which provides carrier-free ^{188}Re as either perrhenate or perrhenic acid for radiolabeling various therapeutic agents. Large, clinical-scale $^{188}\text{W}/^{188}\text{Re}$ generators have been developed, and a clinical prototype was patented in FY 1994. A cooperative R&D agreement (CRADA) has been established with RhoMed, Inc., in Albuquerque, New Mexico, for evaluation of new ^{188}Re -labeled agents for cancer therapy, and the generator system has been licensed to Isotope Product Laboratories, Inc., Burbank, California, for regulatory approval and commercialization. Optimization of the reactor preparation and processing of a variety of other radioisotopes of biomedical interest is also in progress.

A variety of ORNL agents are being evaluated in both preclinical and clinical studies, with more than 20 medical cooperative programs at university hospitals and research institutions in the United States, Europe, Asia, and Australia. These programs represent an effective mechanism for further evaluation of agents developed through collaboration with programs featuring special expertise in cardiology, oncology, and neurology. ORNL-developed agents include the ^{188}Re -labeled antibodies for cancer therapy; multiple-center trials are expected to be initiated in 1996 with ^{188}Re phosphonates for treatment of bone pain from cancer and new ^{123}I ligands for brain and heart imaging. Research in this program continues to receive international recognition, and a variety of invention disclosures, patents, and licenses have been consummated. The balance between basic R&D at ORNL and interaction with other institutions forms the basis for the continued strength of this program. Research efforts will continue to be expanded in the area of molecular nuclear medicine.

Molecular Immunology • Some of the proteins on the surface of cells are tissue-specific and may be altered in kind and amount in the carcinogenic process. We have developed monoclonal antibodies (MAbs) that recognize epitopes on a glycoprotein (thrombomodulin) that is expressed exclusively by lung vascular endothelial cells. This glycoprotein target provides opportunities for the use of MAbs for imaging both vasculature and tumors. This model system is being used to generate preclinical data on the efficacy of tumor vasculature targeting. An alpha-emitting isotope (^{213}Bi) is delivered to tumor vasculature for therapy of perivascular tumors. These studies are in parallel with use of this isotope at the Memorial Sloan-Kettering Cancer Center to treat lymphoid cancers. Liposomes can be targeted with these MAbs, with the possibility of targeting chemotherapeutic agents. They may also be used to deliver specific genes to cells for genetic-based therapy.

New research focuses on the interactions of tumor cells with host vascular endothelial cells, which lead to either neovascularization or metastases. Several adhesion molecules, growth factor/receptor combinations, and proteases have been implicated in these interactions. New MAbs that react with tumor blood vessel cells of the rat are being studied. Target molecules include flt-1, the receptor for vascular endothelial cell growth factor, and

the vitronectin receptor, an integrin molecule implicated in neovascularization of tumors. Antigens expressed on tumor endothelial cells provide excellent targets for MAb-directed delivery of short-lived radioisotopes. The efficacy of this approach in inhibiting angiogenesis and tumor growth will be evaluated in rat model tumor systems. Some of the MAbs developed in this work are now being distributed commercially.

Superconducting Super Collider—KS

This task supported the preparation of National Environmental Policy Act (NEPA) documentation required for constructing and operating the Regional Medical Technology Center (proposed by the State of Texas) on the Superconducting Super Collider site. The NEPA documentation is complete, and the environmental assessment was approved in May 1995.

Laboratory Technology Applications—KU

The Energy Research Laboratory Technology Applications (ER-LTA) program helps to bridge the gap between R&D and commercialization. This program provides a range of mechanisms for joint efforts between the national laboratories and industry: cooperative R&D agreements (CRADAs), personnel exchanges, technology maturation, and technical assistance. ORNL management of DOE-ER projects funded through this program is the responsibility of the Office of Science and Technology Partnerships (Partnerships Office), which oversees all technology transfer activities at the Laboratory. These activities are coordinated with the Lockheed Martin Energy Systems, Inc., Office of Technology Transfer.

The ER-LTA technology focus areas for ORNL are materials, energy and environment, and manufacturing. The majority of projects under this program will fall into these areas. There is also an emphasis on participation in broad industry consortia such as the American Textile Partnership (AMTEX) and the Partnership for a New Generation of Vehicles (PNGV). Efforts to increase small business participation are continuing, with the objective of executing 50% of projects with small businesses.

ORNL's funding for this program has grown steadily, with a tenfold increase since FY 1991. As the only source of funding for commercially attractive developments that currently have no DOE programmatic support, the ER-LTA program is an important resource for the laboratories.

Current Activities • ORNL is engaged in a variety of technology transfer activities, including CRADAs with outside institutions and consortia, user agreements, exchanges of personnel between the Laboratory and universities or industry, and technical assistance to industrial firms. Efforts span the range from basic research to prototyping equipment, developing products, and effecting improvements in manufacturing and processing; most of these efforts are described in the appropriate programmatic areas in this section.

The Partnerships Office is the focal point for cooperative interactions between ORNL and outside groups and individuals. Established in 1989 as the Office of Guest and User Interactions to facilitate collaborative R&D and access to the Laboratory, the Partnerships Office serves as the primary contact for the designated user facilities at the Laboratory, provides assistance with the entrance and approval procedures for both domestic and foreign national assignments, negotiates user agreements, provides support services for research guests, and manages all programmatic and approval processes for CRADA activity at ORNL.

A major responsibility of the Partnerships Office is the management of the ER-LTA Program, which provides funding for many of ORNL's technology transfer activities.

Both the user program and CRADAs address the DOE mission to improve the economic productivity of U.S. industry by leveraging industrial and government resources to address industrial problems and by more effective use of the DOE facilities by external groups. Currently, the ORNL portfolio of ER-LTA projects that are approved/executed includes 34 large spin-off CRADAs; 28 small CRADAs; 10 personnel exchanges; 10 technology maturation projects; and 5 technical assistance projects. More than 40% of these joint efforts are with small businesses.

Efforts to encourage more technology transfer between the Laboratory and small businesses are continuing. ORNL has a Minority Business Office that serves as the focal point for projects involving minority businesses. The Partnerships Office will also have a focused effort to encourage more interaction with small businesses. Much of this activity is expected to occur in the technical assistance area, where the ORNL Partnerships Office will be working closely with the Energy Systems Regional Assistance Program.

CRADAs • CRADAs are funded as large spin-off, multiyear projects or as small (<\$100,000), one-year efforts. A call for proposals for multiyear CRADAs is issued once each year. Proposals are reviewed and ranked by the submitting divisions, by a Laboratory Selection Committee, and by external reviewers. Selected projects are submitted to the Headquarters Program Office for concurrence.

A steadily increasing number of companies are entering into cooperative partnerships with the Laboratory to gain access to the significant scientific resources and skills that exist here (see Fig. 5.1). Furthermore, the leveraging of research dollars through cost-sharing is beneficial to both parties. At the end of FY 1995, ORNL's cumulative total for CRADAs was 219 (including joint ORNL/Y-12 projects), representing commitments of more than \$200 million split approximately equally between federal monies and the private sector.

The ORNL CRADA program includes a broad spectrum of programs and technologies. Among the areas represented:

- Advanced materials, 43%
- Advanced computing, modeling, and simulation, 9%
- Advanced manufacturing and process technology, 9%
- Bioscience and biotechnology, 6%
- Advanced energy technologies and conservation, 23%
- Environmental science, 10%

Individual CRADAs are discussed in the appropriate programmatic areas in this section.

Industrial Consortia • The ER-LTA program initiated the first of the large, multi-laboratory, broad cooperative partnerships with industry, the AMTEX partnership. This effort, now in its third year, is a joint project with DOE's Office of Defense Programs. The ten participating laboratories are performing work focused on five major areas: improved materials and processes; analysis, simulation, and computer integration; environmental quality and waste minimization; energy efficiency; and apparel automation. ORNL is the lead laboratory for the Computer Aided Fabric Evaluation (CAFE) and On-Line Process Control projects and is performing tasks in three other initiatives—the Demand Activated Manufacturing Architecture (DAMA), the Textile Resource Conservation (TReC), and the Rapid Cutting projects. A new effort in which ORNL is the coordinating laboratory is a special procurement in support of the DAMA project. The objective of this College/University

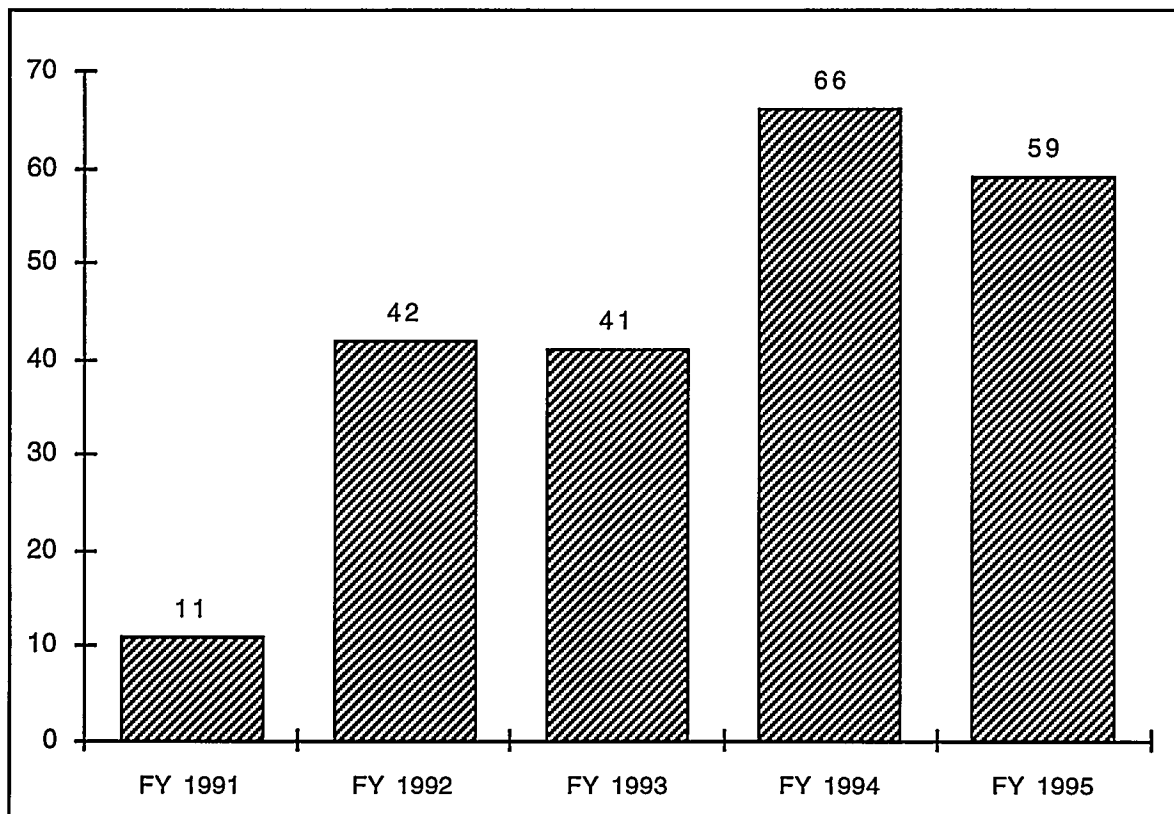


Figure 5.1

CRADAs established at ORNL from FY 1991 through FY 1995. Cumulative total of 219 includes joint ORNL/Y-12 CRADAs.

Research Program is to enable colleges and universities to provide research in areas with potential impact on the design and implementation of the DAMA electronic marketplace.

ORNL continues to work toward developing a new partnership with the aluminum industry. A workshop held in fall 1994 attracted representative of all the DOE laboratories and all of the major aluminum companies. A prioritized list of potential joint efforts was identified. The American Society of Mechanical Engineers and the Aluminum Association are working with ORNL to structure this partnership to most effectively pursue projects that involve either single partners or several companies with multiple laboratories. Both DOE-ER and the Office of Energy Efficiency and Renewable Energy are working toward increasing opportunities for joint efforts with the aluminum industry.

The PNGV is also expected to present opportunities for cooperative projects during the planning period. See Sect. 5.1.2.1 for a description of ORNL participation in the PNGV.

User Facilities • The focus for many ORNL technology transfer activities is provided by user centers and programs. Educational institutions and industries make extensive use of designated user facilities to carry out R&D for educational purposes and to develop new products and processes. The strong programmatic emphasis on energy efficiency, fossil fuels, advanced computing, environmental science, superconductivity, and defense technologies provides a firm basis for cooperative working relationships with industry.

ORNL's designated user facilities and statistics on their use in FY 1994 are listed in Table A.4 in the Appendix. One of ORNL's most heavily used facilities in the past, the Holifield Radioactive Ion Beam Facility, is undergoing modifications (see Sect. 5.1.1.1) and

is expected to resume operations as a user facility in early FY 1996. In FY 1994, experiments were conducted at ORNL user facilities by 829 researchers from 256 institutions. The number of industrial users grew from 102 to 131, representing 74 companies.

The Computational Center for Industrial Innovation (CCII) was designated a user facility in FY 1994. The CCII was established to expand the participation of industry in the programs of the ORNL Center for Computational Sciences. Its objectives include providing U.S. industry with access to massively parallel processing and with opportunities to collaborate with ORNL scientists and engineers to generate timely and innovative technical solutions to real-world problems. The first major industrial user, Reynolds Metals Company, became a member in December 1994.

A proposal to designate the Metrology Research and Development Laboratories (MRDL) as a user facility was approved in June 1995. The MRDL provides a unique capability in the area of measurement R&D, with an emphasis on calibration and precision measurements that require multidisciplinary resources. It currently provides measurement traceability to ORNL scientific staff in more than 20 measurement disciplines as the primary calibration standards laboratory.

Of the 56 new agreements executed during FY 1994, 8 were proprietary. In addition, 126 new projects were initiated under existing agreements. For the first time in the history of the ORNL program, users were required to make advance payments for reimbursable costs.

Guest Research • Guest scientists are a valuable component of ORNL's research staff. Their assignments, which range from two weeks to two years, broaden the Laboratory's base of expertise and support its mission of scientific cooperation and technology transfer. The Partnership Office supported 4053 visits in FY 1994 by scientists and engineers from universities, industries, and other federal institutions. Of this number, 985 were industrial guests. A new database, with improved capabilities for sorting information, allows the Partnership Office to present more accurate numbers for guests for the past three years. These statistics are shown in Table 5.3.

Long-Range Plans • ORNL will continue to apply its institutional competency in development and operation of research facilities through the establishment of new user centers as appropriate to support the Laboratory's mission. Section 5.1.7 describes activities, existing and planned, to extend the success of the national user facility concept to new areas.

ORNL will increase its outreach efforts to small and medium-sized businesses. This effort will be focused on increasing awareness among these firms of cooperative research and technical assistance opportunities. These businesses are also good candidates for partnerships with the Laboratory under the Small Business Technology Transfer (STTR) Program, which is supported by DOE and other government agencies.

The technology transfer plan for Lockheed Martin Energy Systems, Inc., is summarized in Sect. 7. Patent and licensing projections are presented in that section.

5.1.1.2 • Office of Nuclear Energy, Science and Technology

Nuclear Energy R&D—AF

Commercial Reactor Programs • Assuring the safety, cost performance, and availability of light-water reactors (LWRs) is important to the nation's energy security. Responsibility for the evolution of advanced LWR designs is primarily in the hands of industry, but DOE continues to fund support of design certification and associated review tasks. ORNL's current involvement in LWR development is primarily in design reviews, general

Table 5.3
Guests at ORNL by fiscal year

	1992	1993	1994
Federal agency	68	70	75
Foreign institution	75	81	84
High school faculty and students	147	135	167
Leased personnel	364	361	344
University			
Faculty	400	415	466
Postdoctoral	138	199	242
Graduate student	301	319	334
General	811	858	1016
Self-employed consultant	269	281	340
Industry	<u>818</u>	<u>862</u>	<u>985</u>
Total	3391	3581	4053

cost studies emphasizing decommissioning cost, and development of specialized technologies such as passive-safety design features and improved control systems. Future work is expected in enhancing the safety margins for existing LWRs deployed in the United States and around the world, including involvement in the DOE cooperative effort with Japan's Nuclear Power Engineering Corporation on LWR technology development and information exchange.

DOE's joint program with the Electric Power Research Institute (EPRI, see Sect. 5.2.2.1) to demonstrate how modern instrumentation and control (I&C) technologies can be used to improve the operational safety margins of nuclear power plants will be performed by ORNL and managed through the LWR technology center at Sandia National Laboratories. The program replaces the CRADA between ORNL and EPRI that has been in place since FY 1992. The program supports the need for most existing nuclear plants to upgrade old I&C systems because of the lack of spare parts and because of operational and maintenance problems. Equipment suppliers for I&C have replaced older product streams with digital-based products that have yet to be approved by the U.S. Nuclear Regulatory Commission for nuclear applications.

The Gas Turbine-Modular Helium Reactor (GT-MHR) program has emphasized a gas turbine direct cycle plant with a core outlet temperature of 850°C and a power level of 600 MW(t). The high plant efficiency (approaching 50%) associated with the GT-MHR results in calculated power costs that are competitive with or better than the power costs of LWRs and fossil plants. Further, the safety and investment protection features of the GT-MHR are outstanding. ORNL has been involved in technology development with emphasis in fuel performance demonstrations, fission product behavior, and structural metals. This program is to be closed out in FY 1996.

Radioisotope Thermoelectric Generator Production • DOE provides radioisotope thermoelectric generators (RTGs) to the National Aeronautics and Space Administration (NASA) for space missions. ORNL produces carbon-bonded carbon fiber insulator piece parts (sleeves and disks), iridium-alloy cladding products (blanks and foil), and iridium powder for use in a heat source portion of the RTGs. As part of the ORNL program, the Oak Ridge Y-12 Plant makes clad vent sets and weld shields from the products and powder. This

work falls into three categories: (1) fabricating, inspecting, and testing operations; (2) iridium inventory management; and (3) technology development to support the possible use of advanced materials and manufacturing techniques for future NASA missions.

Future manufacturing and production of blank, foil, and clad vent set hardware and sleeve and disk parts will be undertaken for the anticipated NASA Pluto Fly-by Mission, as well as for any other future missions. Schedule and budget planning are uncertain owing to lack of specific guidance from NASA and DOE.

In 1996–2001, the Cassini and base technology efforts will be continued (1) to maintain a capability to produce the piece parts and hardware for anticipated follow-on missions after production for the Cassini mission is complete and (2) to obtain materials, material properties, and process improvements that will provide more margin with respect to specification limits, lower costs, and improved yields of sets and hardware. For example, studies have shown that new dopant alloys containing 30 to 40 atomic parts per million (appm) of cesium and 10 to 20 appm of thorium would have substantially better weldability than the currently used DOP-26 alloy, with comparable high-temperature impact ductility and grain growth. Therefore, a new alloy will be scaled up to a half-size ingot to extend the database for prototypically processed material.

Other research will be directed at extending the ultrasonic technique to provide additional engineering data on indication position using time-of-flight measurement and indication characterization using B-scans. Other development activity will include the design and characterization of a carbon-carbon composite structure of cylindrical shape and intermediate density, optimized for maximum energy absorption, to permit qualifying tests as the heat source graphite impact shell.

Initiative

Production of ^{238}Pu in HFIR/REDC

In the past, U.S. supplies of ^{238}Pu were produced in facilities (now closed) at DOE's Savannah River Site. In 1994, the DOE Radioisotope Facilities Task Force reviewed the capabilities of several DOE sites and determined that ORNL's High Flux Isotope Reactor (HFIR) and Radiochemical Engineering Development Center (REDC), coupled with the Radiochemical Development Facility (RDF) in Building 3019, provide an excellent potential capability for the production of ^{238}Pu . Although DOE has not yet committed to a decision on a domestic ^{238}Pu supplier, ORNL received some financial support in FY 1995 for long-lead-time activities relating to irradiation of neptunium targets in HFIR.

The ORNL ^{238}Pu production option would involve transfer of neptunium as

NpO_2 from the Savannah River Site to the RDF for storage, target fabrication, target irradiation in HFIR, and target processing in Building 7930 of the REDC. These steps, shown schematically in Fig. 5.2, are briefly discussed here. Target irradiation and target recovery could begin as early as FY 1999.

Neptunium storage. The current inventory of neptunium is stored at the Savannah River Site in the form of a nitrate. Plans call for conversion of this material to NpO_2 in 1998 or 1999, yielding about 300 kg of material. The RDF has been identified as the preferred site for neptunium storage. This facility serves as a national repository for ^{233}U and has all necessary safeguards and security systems, as well as appropriate alpha radiation containment and monitoring systems.

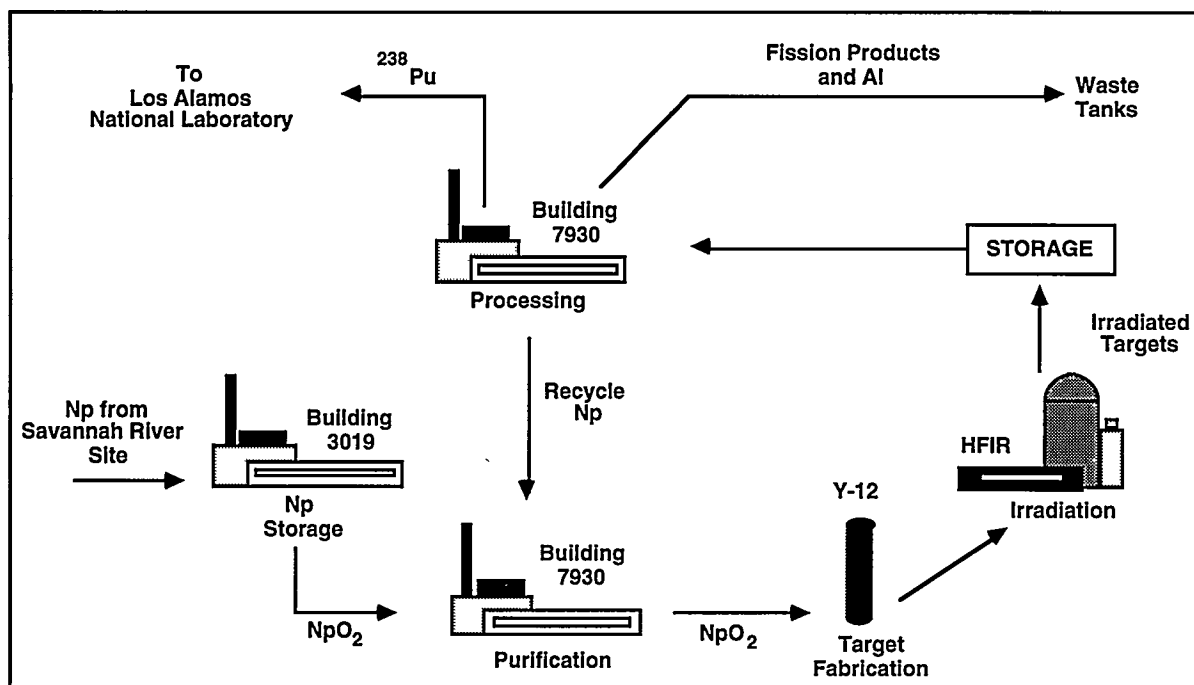


Figure 5.2
Oak Ridge Complex alternative for ^{238}Pu production.

Target fabrication. An important aspect of this initiative is the development of an irradiation target design that can be readily fabricated and provide high NpO_2 loading while achieving good heat removal. The reference target proposed by ORNL uses target plates fitted into slotted cylindrical aluminum tubes. Candidate target fabrication facilities are ORNL, the Oak Ridge Y-12 Plant, and the Babcock & Wilcox Naval Nuclear Fuel Division in Lynchburg, Virginia.

Target irradiation. The most cost-effective HFIR option is estimated to produce ≈ 3.35 kg/year of ^{238}Pu , containing 1–5 ppm of ^{236}Pu , from an annual ^{237}Np target loading of 22.1 kg. These calculations and operating experience with HFIR indicate that the proposed ^{238}Pu production approach should not have a significant impact on other HFIR users, except that the proposed target loading would replace some of the sites now used for iridium isotope production. However, no long-term commitment for iridium isotope production is in place.

Target processing. Chemical processing of irradiated neptunium targets and scrap plutonium would be performed in Building 7930 of the REDC. The REDC is the production, storage, and distribution center for DOE's Heavy Element Research Program. Building 7930 is a heavily shielded hot cell facility designed for remote operation. In planning these activities for the REDC, a process flow sheet was adapted from those previously used at the Savannah River Site and the Hanford Engineering Development Laboratory to determine equipment requirements. The operation was sized for processing 12 kg of ^{238}Pu each year, including irradiated targets from HFIR (yielding 3.35 kg) and the Advanced Test Reactor (yielding 2 kg), and for recycling ^{238}Pu scrap generated by pelletization and encapsulation at the Los Alamos National Laboratory. This activity confirmed the attractiveness of the two available uncontaminated hot cells located in Building 7930. Because these processing steps are similar to the transuranic processing currently being

performed by the REDC, the process is well understood and is thought to represent minimal technical risk.

Estimated costs. Required start-up activities include facility modifications, equipment purchase, obtaining appropriate

operating approvals, and experimentation to support design activities. Startup costs of \$26 million to \$36 million are projected, with annual operating costs of \$9 million to \$14 million, as shown in Table 5.4.

Table 5.4
Budget projections by fiscal year for ^{238}Pu production at HFIR/REDC^a
(\$ in millions—BA)

	1996	1997	1998	1999	2000	2001
Total funding	2.9	10.0	17.8	20.5	14.0	14.0

^aFunding is sought from the Office of Nuclear Energy under Nuclear Energy R&D—AF.

Naval Reactors—AJ

Radiation Shielding Information Center • The Office of Naval Reactors provides some funding for the Radiation Shielding Information Center (RSIC), which supplies specialized information, computational tools, and a suitable cross-section database to DOE programs by serving as a focal point in the community for technology exchange and making available the latest developments in computing and other technology, data libraries, and bibliographic information. RSIC is described in Sect. 5.1.6.2.

Isotope Production and Distribution Program—ST

The mission of the Isotope Production and Distribution Program at ORNL is to supply enriched stable isotopes, selected radioisotopes, and related technical services for research, medical, and industrial applications. This continues to be a significant and highly valued program that uses the unique capabilities and facilities located in Oak Ridge. Radioisotopes are produced in the High Flux Isotope Reactor (HFIR); enriched stable isotopes are produced in the calutron electromagnetic separators located in the Isotope Enrichment Facility at the Y-12 Plant. These isotopes are used for many purposes in research, medicine, and industry. The program mission includes the development and evaluation of methods for isotope production and separation. Specialized technical services such as preparation of high-purity isotopes and unique chemical and physical forms are also performed.

The Isotope Production and Distribution Program was restructured by Congress in FY 1995. Funds are now appropriated annually for the production of nonprofitable rare isotopes for research uses and isotopes that meet crucial needs in the United States. In addition, the program will continue to produce isotopes for commercial sales when no other supply exists. Guidelines for the program are described in the DOE National Isotope Strategy. The Oak Ridge Center for Isotope Technologies, described in Sect. 5.1.7.3, would provide a mechanism for coordinating the resources of the national laboratory system, other organizations (both public and private), and other nations.

5.1.1.3 • Office of Science Education and Technical Information

ORNL recognizes that its unique scientific and technical resources will play a role in enhancing global competitiveness and the development of a diverse, well educated, scientifically literate work force. Science education activities are discussed here. Scientific and technical information management, as a cross-cutting function, is discussed in Sect. 5.1.6.2.

University and Science Education—KT

The ORNL-obligated portion of DOE's University and Science Education Program supports the administration and conduct of mathematics and science education activities at all academic levels—precollege (kindergarten through 12th grade), undergraduate, graduate, and postgraduate students and faculty. In addition to faculty and student programs, the focus of ORNL's education programs includes local, state, regional, and national systemic reform initiatives, public science literacy, and educational technology.

These activities are coordinated through the ORNL Office of Science Education (OSE), which is part of the Laboratory's Computing, Robotics, and Education directorate. This organizational structure not only serves to emphasize the role of education as one of ORNL's primary missions, but also establishes within the directorate a strong community of interest and a supporting framework for OSE's outreach in educational technology.

Science education is recognized as one of ORNL's institutional competencies (see Sect. 2), closely linked to the core competencies and to the technical foundations that cross-cut them. A growing array of educational outreach and student/faculty research participation programs is designed to

- strengthen science and mathematics teaching at all levels, while encouraging student interest and learning performance;
- build and diversify the educational pipeline in disciplines that directly support DOE strategic goals and missions; and
- help to ensure the future supply of people with outstanding scientific and technical skills.

Mission, Vision, and Goals • The mission, vision, and overarching goals of OSE are as follows.

Mission • Use Lockheed Martin, ORNL, local, state, regional, and national resources to be a world-class Regional Science Education Center especially for the southeastern United States, with strong supporting constituencies at education and research institutions.

Vision • Become the benchmark for the premier and most comprehensive science education program in the DOE family of laboratories and contractors.

Overarching Goals • Build educational, training, and research partnerships that serve to

- enhance the capability, quality, and diversity of the nation's scientific and technical work force;
- strengthen ORNL and Energy Systems technical capabilities, supporting constituencies, scientific and technical staff, and contributions;
- continue the development of education as a primary mission of the Laboratory consistent with Public Law 101-510 (Department of Energy Science Education Enhancement Act of 1990) and Executive Order 12821 (Improving Mathematics and Science Education in Support of the National Goals), November 16, 1992;
- support National Education Goal 5: "By the year 2000, U.S. students will be the first in the world in science and mathematics achievement," and

- contribute collective resources to the success of national science and technology initiatives, including those in mathematics and science education, high-performance computing and communications, biotechnology research, advanced manufacturing R&D, global change research, and emerging opportunities such as computational biology.

Highlights • ORNL's educational focus complements that of degree-granting institutions. The primary goal is to provide mentored, inquiry-based, "hands-on" learning and research experiences for students and teachers. A major effort is aimed at building new educational, training, and research partnerships—with other federal agencies, such as the Appalachian Regional Commission, the National Aeronautics and Space Administration, and the National Science Foundation, that have joined with DOE; with schools, colleges, and universities; with educational consortia and museums, both regionally and nationally; and with private-sector institutions and organizations.

One model is Tennessee's oldest and largest academic Center of Excellence, the Science Alliance between ORNL and the University of Tennessee at Knoxville (UTK). This academic outreach is also reflected in well over \$20 million annually in subcontracted R&D with university partners.

Equity and diversity are a high priority in ORNL educational programs. Established collaborations with multicultural educational institutions not only support the continuing development and growth of these institutions as academic centers of excellence but also enable DOE and its contractors to diversify their present and future work force.

Through the ORNL Regional Science Education Center, opportunities are provided for more than 25,000 students and teachers each year. Table A.5 in the Appendix lists these activities and the number of participants. They include

- partnerships with more than 50 elementary and secondary schools and/or school systems, colleges, and universities, emphasizing outreach to underrepresented and underserved populations (women, minorities, the economically disadvantaged, and people with disabilities);
- student and faculty research participation through DOE's long-standing University Laboratory Cooperative Program and through two newer initiatives, the undergraduate Science and Engineering Research Semester and the secondary-level Teacher Research Associates (TRAC) program;
- the Oak Ridge Educational Network, which connects schools and individuals to the Internet;
- the Ecological and Physical Sciences Study Center, now in its 12th year as ORNL's core program for K-12 students and teachers, which serves up to 24,000 participants annually through 40 different half-day instructional units;
- Project SMART (Science/Math Action for Revitalized Teaching), a prototype rural-urban partnership that links three East Tennessee school systems, ORNL, and the Oak Ridge Institute for Science and Education (ORISE);
- the Adventures in Supercomputing teacher institutes and student programs, now reaching schools in five states under the High Performance Computing and Communications Program;
- the DOE Lyndhurst Fellowship Program, conducted in cooperation with UTK, which prepares scientific and technical professionals for second careers as teachers;
- the five-state Academy for Teachers of Science and Mathematics, another UTK/ORNL partnership, with federal, state, and corporate (Lockheed Martin) support, and many other teacher enhancement activities;

- aggressive outreach to multicultural educational institutions through customized internships and other research participation opportunities;
- two ORNL-based UTK graduate schools—the UT-ORNL Graduate School of Biomedical Sciences and the UT Graduate Program in Ecology—and joint institutes and research centers in many other areas;
- participation in the DOE Science and Technology Alliance, which links ORNL, Los Alamos National Laboratory, and Sandia National Laboratories with four minority educational institutions;
- the Oak Ridge Graduate School Fair and the annual Women in Science and Technology Conference, both jointly sponsored with ORISE; and
- postgraduate training initiatives, including the new ORNL Postdoctoral Research Associates Program, which now bring well over 200 young investigators to the Laboratory for extended assignments with ORNL mentors.

More than 35 programs at all levels—K-12, undergraduate, graduate, postgraduate, and faculty—enable students and teachers to enrich their learning experience or advance their professional development through interactions with ORNL staff and access to ORNL facilities. The Laboratory works closely with the ORISE Science/Engineering Education Division and with Associated Western Universities in administering both summer and academic-year research participation programs.

All of these academic partnerships represent a mutually beneficial and highly cost-effective way to support DOE programmatic goals while providing valuable education and training for the participants. Student and faculty interactions have also proved to be important in meeting staff recruitment and development goals (see Sect. 6.2.1) and in furthering the process of technology transfer through both on-site and on-campus R&D collaborations.

In response to possible reductions in funding, options are being developed for partial support of selected precollege science education programs through financial participation by external partners on a fee-for-service basis.

5.1.2 • Energy Programs

5.1.2.1 • Office of Energy Efficiency and Renewable Energy

ORNL works on a wide range of programs for the Office of Energy Efficiency and Renewable Energy (DOE-EE). The mission of the ORNL Energy Efficiency and Renewable Energy (EE/RE) Program is to assist DOE-EE in accelerating the development and deployment of sustainable energy technologies, thereby creating a cleaner environment, a stronger economy, and a more secure future. The program employs an integrated approach to achieve this mission: it combines applied research with technology development and deployment activities; it draws on the expertise of multidisciplinary teams capable of tackling large and complex problems; and it involves a wide array of industrial, academic, and public-sector partners in the definition, execution, and assessment of its activities. Widespread use of its research results and swift transfer of its technologies into commercial applications are accomplished through user facilities, cost-shared subcontracts, cooperative R&D agreements (CRADAs), and licensing, as well as publishing, exhibits, and participation in conferences and symposia.

Moderate decreases in funding levels are expected in FY 1996 and FY 1997. Funding is then expected to be relatively constant for the remainder of the planning period. New

projects are proposed in hydrogen research (program AR), the industrial sector (program ED), and the transportation sector (program EE).

Electric Energy Systems—AK

ORNL provides field management of three programs for the Office of Energy Management: the Superconductivity Program for Electric Power Systems, Power Transmission and Distribution Technologies, and Electric and Magnetic Field (EMF) Bioeffects. ORNL also provides assistance in engineering and analytical studies and technical support for planning and decision-making.

The goal of the Superconductivity Program for Electric Power Systems is to develop the technology base needed for U.S. industry to proceed to commercial development of electric power applications of high-temperature superconductors. The three major elements of the program are wire development, electric power applications development, and the Superconductivity Partnership Initiative. Superconductivity collaborative agreements are the principal mechanism used to enable joint R&D projects with industry and universities; these projects optimize the use of program resources for the benefit of all participants. Completion of the superconductor generator project with General Electric Company is expected in early FY 1996. In a collaborative project with Intermagnetics General Corporation, demonstration of a prototype high-temperature superconducting transmission and distribution application is scheduled for late FY 1996. Demonstration of a superconducting coil for ac applications is expected by the end of FY 1997. ORNL is a partner with Southwire Company in a CRADA with the goal of developing a high-temperature superconducting underground cable.

In Power Transmission and Distribution Technologies, ORNL is working with the DOE power marketing agencies, the Electric Power Research Institute, and other interested parties to improve electric system capacity, flexibility, and efficiency while maintaining high reliability. The program includes development of real-time system control to allow operation of power systems closer to thermal limits; high-capacity options such as high-voltage dc transmission; development of advanced planning tools for systems operated in real time; and evaluation of opportunities for integration of advanced energy storage technologies and renewable generation. Milestones for FY 1996 include a cost/benefit study of high-voltage dc transmission vs other capacity-enhancing technologies. In FY 1997, algorithms will be developed for automated control of transmission and distribution systems using artificial intelligence techniques. Funding in this area is expected to decrease in FY 1996; subsequent funding levels are uncertain.

In EMF Bioeffects, ORNL is assisting DOE in implementation of the National EMF Research and Communications Program through the development and implementation of engineering and science research plans. Activities include exposure assessment, development of recommendations for standardizing measurement techniques, source characterization, and field management. ORNL is one of four government laboratories involved in efforts to replicate EMF bioeffects findings reported in the literature. Several characterization studies of magnetic fields in industrial and commercial environments will be completed in FY 1996.

Funding for program AK will decrease significantly over the planning period.

Energy Storage Systems—AL

ORNL's program to develop thermal energy storage technologies for industries and buildings currently consists of cost-shared subcontracts for development of wallboard with

enhanced heat capacity and development of a low-temperature thermal energy storage system for off-peak refrigeration. The program is to be closed out in FY 1996.

ORNL research on high-speed rotating equipment focuses on technology development for high-speed energy storage flywheels. Specific technology is being developed for utility applications (power quality, emergency backup, load leveling), transportation (cars, buses, boats, trains), space vehicles, and military pulse power applications. ORNL manages DOE's national flywheel program, which is closely coordinated with that of the Advanced Research Projects Agency. The Laboratory is continuing to develop advanced technology in several areas, such as advanced composite materials and power electronics, that support the evolution of high-performance flywheel systems. The on-site spin test facility is available as a national resource for high-speed flywheel testing.

Geothermal Systems—AM

ORNL has provided technical and analytical support for evaluating the environmental impacts of geothermal development in the state of Hawaii. The program was closed out in FY 1995.

ORNL is also conducting a continuing study on chemical reactions in geothermal systems for the DOE Idaho Operations Office (DOE-ID) and the DOE-EE Geothermal Division. A program that provides support to the California Energy Commission in an assessment of geothermal heat pump performance and economics was completed in FY 1995.

Funding in program AM is expected to decline after FY 1995 because of project completions.

Hydrogen Research—AR

Building on the demonstration of hydrogen production in an evacuated photobiological reactor, ORNL is investigating hydrogen production by photosynthetic water splitting as a renewable source of elemental hydrogen. A photobiological reactor to produce hydrogen in subambient atmospheres has been designed; measurement of hydrogen production rates by selected algae will continue in FY 1996. This research also receives support from the Office of Fossil Energy (DOE-FE).

A new study using advanced materials for hydrogen storage has been initiated. ORNL has proposed studies to investigate advanced technologies for hydrogen storage, separations, and sensors.

Funding for program AR is expected to increase moderately over the planning period.

Hydropower—CE

ORNL provides research and other technical assistance to DOE-HQ and DOE-ID on environmental aspects of DOE's Hydropower Program. The second volume of the Environmental Mitigation Study, covering fish passage, was completed in FY 1994. In addition to ongoing research on mitigation practices, work in FY 1996 includes support to DOE's Advanced Hydropower Turbine Initiative. Funding is expected to remain level through the planning period.

Solar Energy—EB

ORNL provides field management for the Biofuels Feedstock Development Program (BFDP), a national program for the development and demonstration of environmentally acceptable, commercially viable biomass supply systems based on energy crops. Areas of emphasis include model wood and herbaceous energy species; environmental research; systems integration and analysis; scale-up, feasibility, and demonstration; and data and information management. Energy species research has emphasized selection, characterization, and improvement through breeding and genetic studies, as well as tolerance to biotic and abiotic stresses. Pest-resistant *Populus* clones will be identified for regional testing in the north central United States in FY 1996. First-generation breeding work for pedigreed *Populus* for the southeastern United States will be completed in FY 1997.

The BFDP has completed a study co-sponsored by the Tennessee Valley Authority to determine the costs and environmental impacts of producing energy crops in the Tennessee Valley and surrounding region. An integrated analysis will quantify and characterize the potential production of energy crops for an 11-state region across the South and Midwest. Results from regional analyses will provide input for studies examining the impacts of energy crop deployment on regional landscape ecology, water quality, and water balances.

In other solar energy projects, ORNL has investigated strategies to speed the adoption of photovoltaic systems in residential and light commercial buildings; this effort is to be completed in FY 1996. The Laboratory is providing support for the establishment and implementation of an "Energy for Sustainable Development Center" in India. A project to demonstrate the use of fluidized-bed bioreactors for production of ethanol began in FY 1994. A pilot-scale bioreactor was constructed, and tests with various biocatalysts are scheduled for FY 1996.

Funding is expected to decline slightly through the planning period.

Buildings Sector—EC

ORNL is responsible for field management in four program areas: Building Thermal Envelope Systems and Materials, Building Equipment Technology, Existing Buildings Research, and Buildings Implementation and Deployment.

The Buildings Technology Center (BTC), one of ORNL's national user facilities, is an integration of the Roof Research Center with other ORNL buildings research facilities. The BTC is designed to aggressively promote the integration of building technologies and is the principal resource for an ORNL-sponsored, competitive Building Energy Technology Internship Program for students from minority educational institutions.

Major building envelope research projects include a CRADA with the insulation industry to compare the performance of foam insulation blown with chlorofluorocarbon (CFC) alternatives to that of conventional CFC-blown foams, and a joint project with Dow Corning, Inc., to examine the efficiency of reroofing with spray-foam insulation over an old, wet asphalt roof. The thermal performance of loose-fill insulation in attics has been characterized in the BTC, and experimental work to eliminate or mitigate the convection effects that decrease the effectiveness of loose-fill insulation in attics continued through FY 1995. An attic system design book will be published in FY 1996.

A new type of foundation block that has been developed offers energy efficiency and termite resistance. A patent application has been filed, and the thermal performance of the

blocks is being tested in the BTC. Licensing partners are being sought to manufacture blocks for a field test to be conducted in FY 1996–FY 1997.

A national consumer labeling procedure for whole-building wall thermal performance is under way. Through the BTC, users are testing energy-efficient advanced wall systems in the Rotatable Guarded Hot Box. The results serve as the basis for a calculation leading to an overall wall R -value accounting for structural interface details (e.g., corners and wall/fenestration couplings).

The building materials program addresses the development and characterization of new and existing insulation materials for buildings and refrigeration equipment. The goal is to develop new, cost-competitive materials that can reduce building energy consumption by 20% by 2010. Specific tasks are conducted in the areas of advanced materials research, existing materials performance, and retrofit insulation. The advanced materials research task has the objective of market introduction of superinsulations ($R \geq 45/\text{in.}$ with a 30-year life) in FY 1997–FY 1998. The existing materials task has the goal of market introduction of a foam insulation ($R \geq 12/\text{in.}$) that is free of hydrochlorofluorocarbons (HCFCs) in FY 1996–FY 1997. The retrofit materials task seeks to develop new, efficient methods of retrofitting insulation within existing buildings; a retrofit insulation with $R \geq 5/\text{in.}$ is expected to gain market introduction in FY 1996–FY 1997.

The goal of the building equipment technology project is to generate new concepts and develop technologies for improving the energy efficiency and load characteristics of energy conversion equipment used in residential and commercial buildings. A worldwide, exclusive license agreement has been signed by Carrier Corporation for the generator–absorber–heat exchange (GAX) absorption residential heat pump technology developed under an ORNL subcontract with Phillips Engineering Company. This technology promises heating efficiency at least 50% better than the best current technology and cooling efficiency comparable to middle-of-the-line electric air conditioning. Technical support to Carrier Corporation in its efforts to bring the technology to the marketplace will continue through FY 1996, with a goal of market introduction in FY 1997. The GAX residential unit is the first in an absorption system family that DOE and ORNL plan to bring to the market through industry partnerships. Other products will serve the light commercial and large building chiller markets with high cooling efficiency. Two different triple-effect chiller cycles patented by ORNL scientists are under development in DOE partnerships with the gas utility industry and absorption chiller manufacturers.

In other technical areas, ORNL is a national leader in CFC/HCFC research for heating, cooling, and refrigeration applications. A CRADA with the Association of Home Appliance Manufacturers (AHAM) has the objective of developing and demonstrating a residential CFC-free refrigerator/freezer that is 50% more efficient than the existing industry standard. AHAM members are scheduled to begin phasing these improvements into their products in 1998.

The DOE/ORNL Heat Pump Design Model, widely used by industry, is being upgraded with new refrigerant, refrigerant blend, and heat exchanger capabilities to help heat pump and air conditioner manufacturers meet the product development and redesign challenges of transitioning from HCFCs to next-generation, ozone-safe fluids with improved product efficiencies. ORNL has also developed and patented a technique that extends the liquid-overfeed (LOF) concept to residential air conditioners and heat pumps. A CRADA has recently been put in place with the Coca-Cola Company to improve the cost-effectiveness and energy efficiency of vending machines using the LOF technology.

The existing buildings research program supports public- and private-sector efforts to improve the energy efficiency of existing residential and commercial buildings. A proof-of-concept test to determine energy savings from replacement of air conditioner compressors is to be completed in FY 1996. Other projects include development of energy efficiency screening programs for commercial buildings, to be completed in FY 1997, and ongoing technical support to state weatherization programs.

The main objective of the buildings technology transfer program is to foster the adoption and use of energy-efficient and renewable technologies, as well as to ensure that research results are transferred quickly, efficiently, and effectively to private- and public-sector users. The program emphasizes strong working relationships with key professional and trade associations and research organizations that serve as intermediaries and brokers in reaching the diverse and fragmented building sector industries, manufacturers, and consumers. The program seeks to identify and carry out technology and information transfer activities that will have a long-term positive effect on the design, construction, and maintenance of energy-efficient and renewable energy buildings and equipment. To this end, the program is building a showcase technology demonstration house in Atlanta, Georgia, that will feature energy-efficient and renewable technologies developed within the DOE Office of Buildings Technology research programs and available on today's market. Other products of the program include a regional task force that focuses on building issues in the southeastern United States and a ZIP Code Insulation Program on CD-ROM that assists consumers in determining the insulation requirements of new and existing houses.

ORNL is assisting DOE-EE in addressing the requirements of the Energy Policy Act of 1992 (EPACT). A project to accelerate the development and commercialization of high-efficiency appliances has several focus areas, including equipment (e.g., high-efficiency laundry appliances and non-CFC chillers), collaboration with energy service companies to remove barriers to the introduction of high-efficiency technology, and cooperative efforts with retailers to accelerate sales of high-efficiency appliances. Another project related to the EPACT consists of an evaluation of technology options available to reduce the losses in new distribution transformers. The final report is scheduled for mid-FY 1996.

Other ORNL efforts in buildings research include a cooperative project with the National Association of Home Builders to identify advanced housing technologies; technical assessments of industrialized housing technologies; technical support to federal infrastructure modernization efforts and public housing authorities, and technical support to a historically black university in execution of research proposals supportive of the objectives of the Office of Building Technologies.

Moderate decreases in funding are expected over the planning period.

Industrial Energy Conservation—ED

ORNL performs applied R&D on four projects for the Advanced Industrial Concepts (AIC) Division. The AIC Materials Project develops new and improved materials and manufacturing technologies for more efficient energy use. High-temperature intermetallic and metallic alloys with high ductility, corrosion resistance, and strength are being developed. Metal-bonded composites are being developed for optimal use at temperatures between those of currently available alloys and ceramics. Coatings and engineered porous materials are being evaluated for various applications. Microwave technology, which offers new and exciting potential for materials with unique properties, is being pursued.

For the AIC Advanced Bioprocessing Concepts Project, fluidized-bed bioreactors are being studied for both three-phase and four-phase operations, including an extraction phase to combine fermentation and separation. Gas-phase bioreactors are also being examined. Predictive models will be developed for use in scale-up of organic acid production. New initiatives will address the use of biocatalysts in the presence of organic media and the use of carbon dioxide for the production of fuels and chemicals. The program also provides support to an annual Symposium on Biotechnology for Fuels and Chemicals. Other projects include research on photobiological reactions for enhanced capture of solar energy and thermal sciences research to investigate concepts such as superconducting thermomagnetic energy conversion.

The continuous fiber ceramic composite (CFCC) program for the Office of Waste Reduction Technologies focuses on development of processing methods for fabrication of CFCC components for industrial applications. CFCCs are light weight, corrosion resistant, and stable at high temperatures. ORNL tasks include (1) technical assistance in project evaluation and industry interaction and (2) R&D in composite design, materials characterization, test methods development, and performance-related phenomena.

A continuing project on materials for advanced industrial heat exchangers provides materials technology support to DOE and its contractors for heat exchanger development projects. Another continuing project on chemical industrial heat pumps is developing high-lift heat pumps that use industrial reject heat to produce plant utility-grade process heating and cooling. Proof-of-concept experiments were conducted in FY 1995. The schedule calls for completion of bench-scale development in FY 1996 and field testing of prototype units in FY 1997.

ORNL and the DOE Oak Ridge Operations Office participate in DOE's Advanced Turbine Systems program, which is co-sponsored by DOE-EE and DOE-FE, by coordinating the materials/manufacturing task, with the goal of developing materials and manufacturing techniques to withstand turbine inlet temperatures greater than 1400°C. An abradable seal coating material was fabricated and evaluated in FY 1995. A report on long-term creep and stress rupture testing will be completed in FY 1996.

ORNL provides technology development support to the Motor Challenge Program, a major initiative in the development of energy-efficient motor systems. Validation and measurement techniques are developed, and a database of existing motors is being compiled.

ORNL conducts two programs for the Separations Division. A project on alternative feedstocks for chemicals and petroleum refining industries is part of a cooperative initiative with four other national laboratories, in which ORNL is responsible for developing advanced technology for bioprocessing and will have an increasing role in thermochemical conversion. An advanced bioreactor system for bioproduction of organic acids was selected in FY 1995. Another project is developing technologies that use industrial cellulosic waste (e.g., wood pulp). Development of a bioprocess to use this resource is expected in FY 1997.

A new project for the Material Processing Division began in FY 1995, with the objective of developing in-line sensors to improve the efficiency of commercial aluminum electrolysis operations.

Four new projects are proposed to the Waste Material Management Division: R&D on a method of separating inked from uninked pulp fibers that could offer significant energy savings in the paper recycling process; enzyme engineering to optimize the amount and activity of enzymes during the pulp bleaching process; analysis of falling film evaporation of spent black liquor in an effort to remove process barriers to adoption of more energy-efficient

and environmentally friendly pulping technologies; and an assessment of the state of harsh-environment process sensor performance and longevity, with identification of those processes and systems for which improved sensor systems would provide the largest gains in energy efficiency, waste reduction, and worker safety.

Funding is expected to decrease slightly over the planning period.

Transportation—EE

The scope of ORNL's work in transportation encompasses materials development, alternative fuels, propulsion technologies, transportation data, and policy analysis. The Oak Ridge Transportation Technology Center (ORTRAN) brings together the capabilities of ORNL, the Oak Ridge Y-12 Plant, and the Oak Ridge K-25 Site in promoting and supporting new research activities focusing on major transportation R&D issues related to energy, environment, and security for the nation and the world. ORTRAN is forging partnerships within the Oak Ridge complex and with other public and private agencies and industry, with emphasis on seven development areas:

- transportation policy and planning,
- advanced vehicle and fuel technologies,
- intelligent vehicle highway system (IVHS),
- advanced defense transportation and deployment systems,
- hazardous materials transportation and handling,
- transportation manufacturing construction technologies, and
- industry and university partnership development.

ORNL and its partners have joined forces with the University of Tennessee to create a new transportation R&D user facility. Plans for development and construction of the facility are being prepared, with initial operation expected to begin in FY 1996.

ORNL provides technical and management support to the Partnership for a New Generation of Vehicles (PNGV), a partnership between the federal government and Ford, Chrysler, and General Motors. The main goal of the PNGV is to develop a commercially viable midsize car with three times the fuel efficiency of today's comparable vehicle, without negatively affecting safety, comfort, purchase and operating cost, or performance, within 10 years. Expertise and unique facilities in engine testing, materials development and evaluation, electronic and electrical devices, flywheel energy systems, and manufacturing technologies have been drawn from the three Oak Ridge sites (ORNL, the Oak Ridge Centers for Manufacturing Technology at the Y-12 Plant, and the Center for Environmental Technology at the K-25 Site). The main mechanism for cooperation between the parties involved in the PNGV is the CRADA; ORNL will coordinate national laboratory CRADA project reviews in FY 1996 and FY 1997. ORNL also coordinated the Vice President's Symposium on energy management technology in late FY 1995.

In the Ceramic Technology Program, ORNL has developed the technology base required for reliable ceramics for use in advanced heat engines and is working to reduce the cost of ceramics, with emphasis on near-term applications in conventional engines. Most of the work will be accomplished by the ceramic industry, with technology support from government laboratories and universities. The technology will be developed in close coordination with the ongoing DOE and industry engine development programs. Milestones in the program include demonstration of an order-of-magnitude cost reduction in manufacturing of ceramic engine components and completion of casting trials for low-expansion ceramics for

exhaust ports in FY 1995 and completion of the development of ceramic life prediction methodology in FY 1996.

The High Temperature Materials Laboratory (HTML) is a significant resource for this and other materials R&D programs. The HTML, one of ORNL's national user facilities, houses dedicated laboratories and special instruments to support advanced materials research. An expert staff works with prospective users to define the details of research proposals and then assists users in conducting the research and in analyzing and interpreting the results. The combination of state-of-the-art instruments and staff expertise is highly effective; user projects span the materials spectrum from superalloys to ceramic composites.

Research is conducted in six user centers in the HTML. One of these, the Machining and Inspection Research Center, is a partnership between DOE-EE, the Office of Energy Research (DOE-ER), and the Office of Defense Programs. The new neutron residual stress facility at the High Flux Isotope Reactor, a partnership between DOE-EE and DOE-ER, is scheduled for full operation in early FY 1996. A surface engineering and wear research center is planned for FY 1996, and an environmental and thermal fatigue center is planned for FY 1997.

The HTML Fellowship Program provides educational opportunities for industrial researchers, graduate students, and university faculty members, emphasizing research conducted in the HTML on materials directly related to the Office of Transportation Technologies mission. Since its inception, the program has hosted five industrial fellows, three faculty fellows, and seven graduate fellows.

Lightweight materials development addresses materials and process technology to aid in automobile weight reduction. Work is under way on adhesive bonding of polymer components. Long-term R&D needs identified by the United States Automotive Materials Partnership are being addressed, especially process modeling, material performance modeling, recycle technology, and new materials development.

Alternative fuels R&D involves a CRADA on improved catalysts and emission controls with General Motors, AC Rochester Division. Catalysts for natural gas and alcohol fuels are emphasized, and the R&D includes materials characterization, bench tests, and detailed measurements of catalyst performance on test stands. A comparison of on-road emission characteristics of conventional and alternative-fuel engines will begin in FY 1996. Projections of performance and efficiency of optimized alternative-fuel engine designs will be developed in FY 1996.

Work in automotive propulsion technology complements our work on alternative fuels utilization by examining and testing concepts for advanced engines. ORNL has project management responsibility for heavy-duty engine emission aftertreatment and alternative fuel technology. CRADA efforts are under way in the Engine Systems Support Technology program. The Advanced Propulsion Technology Center, part of the Oak Ridge Centers for Manufacturing Technology, serves as a development, integration, and evaluation facility for new technologies related to internal combustion engines and powertrains. These technologies include alternative fuels, new materials, diagnostics and controls, and other techniques for reducing emissions and enhancing efficiency. The ORNL Power Electronics Center contributes to the National Power Electronics Building Blocks program to support transportation initiatives and electric energy system programs.

Other projects in propulsion technologies include development of a new generation of high-efficiency electric power inverters and development of flywheel technologies. A new project is proposed to develop compressor and expander technologies critical to the

successful introduction of electrochemical engines using a proton exchange membrane fuel cell system.

ORNL is investigating nonpolluting, cost-effective, and energy-conserving space conditioning systems. A new application arising from this study is the liquid-overfeed mobile air conditioner, which is 20% more energy efficient than existing air conditioners and uses non-CFC refrigerants. Tests of an advanced climate control system began in FY 1995.

ORNL also conducts analyses of transportation data and energy use related to vehicle and engine R&D and fuel economy, sales, and technology trends. Key transportation energy use data are published in the annual *Transportation Energy Data Book*. Major transportation databases are maintained by ORNL for use by the Office of Transportation Technologies. In addition, ORNL provides policy analyses and assessments of fuel economy and clean air considerations.

Funding levels for transportation are expected to remain constant during the planning period.

Technical and Financial Assistance—EF

ORNL provides evaluation and technical support for several programs in the Office of Technical and Financial Assistance. The major current effort is a national evaluation of the Weatherization Assistance Program. Data on a nationally representative sample of program participants and matched control groups were collected and analyzed; estimates of energy savings and cost-effectiveness were published in FY 1994. The Weatherization Assistance Program also sponsored ORNL's development of a National Energy Audit (NEAT). ORNL has provided NEAT and user training to the State Energy Offices and will continue to enhance NEAT in response to user feedback. Building on the results of this research, ORNL is now participating in the design and implementation of a warm climate weatherization initiative.

ORNL research for the Energy-Related Inventions Program focuses on estimating the program's economic, energy, and environmental impacts. ORNL is also providing technical and management assistance to several international initiatives, including the Committee on Energy Efficiency Commerce and Trade, the Asia Pacific Economic Cooperation, and two projects of the International Energy Agency. One is the Center for Analysis and Dissemination of Demonstrated Energy Technologies (CADDET), which maintains an international database of successful energy technologies. The program focuses on demonstration projects or full-scale applications of new technologies. CADDET has two branches: CADDET Energy Efficiency and CADDET Renewable Energy. ORNL is the U.S. Support Office of CADDET Energy Efficiency. The second project is the Greenhouse Gas Technology Information Exchange (GREENTIE). GREENTIE maintains a directory of organizations and technologies that promote the reduction of greenhouse gas emissions and serves as a focal point for information and technology sharing among the 19 member countries.

Funding is expected to remain near current levels over the planning period.

Utility Sector—EK

ORNL's research on the electricity industry deals with various topics related to industry restructuring and competition, as well as resource planning and demand-side management (DSM) programs. Current projects deal with stranded commitments, options for retail customers, unbundling generation and transmission services (ancillary services),

performance-based regulation, analysis of ways to maintain public policy functions ("stranded benefits") in a competitive industry, recent and planned changes in utility DSM programs, and the future of utility DSM.

A study of district heating, cooling, and co-generation to determine energy, economic, and environmental benefits in accordance with the Energy Policy Act of 1992 was to be completed in FY 1995.

Funding is expected to decrease significantly through the planning period.

5.1.2.2 • Office of Fossil Energy

ORNL programs for the Office of Fossil Energy (DOE-FE) cover research in coal, gas, petroleum, and innovative clean coal technology, plus support to the Strategic Petroleum Reserve. The principal focus of ORNL's fossil energy activities, however, is coal. Budgets in this area are expected to remain fairly constant, although the distribution of funds among the various program elements may change.

Coal—AA

Significant programs are under way in materials research, bioprocessing, coal combustion, and environmental analysis support (EAS). A strong budget position has been maintained in materials research, and bioprocessing has experienced growth. Technical support of the Pittsburgh Energy Technology Center (PETC) for projects in India has ended, but support for other coal combustion activities and EAS is expected to remain steady over the next five years.

The ORNL Fossil Energy Program has the technical lead and responsibility for technical management with DOE's Oak Ridge Operations Office for the Fossil Energy Advanced Research and Technology Development Materials Program. This program covers (1) traditional structural materials R&D on ceramic composites and advanced alloys and (2) functional materials (i.e., materials that possess properties important to performance of a specific function, such as solid-state electrolytes and inorganic membranes).

Fiber-reinforced ceramic composites with improved strength and toughness are being produced by the forced chemical vapor infiltration and deposition process developed at ORNL. Ceramic composites have a variety of applications in fossil energy systems; these include 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 and corrosion resistance of composites. Ceramic membranes for the separation of gases in high-temperature and hostile environments are being developed and tested. Development is under way on carbon fiber composite molecular sieves, fabricated from fibers produced from petroleum and coal-derived pitches. Additional ceramic fiber filter technologies are being explored.

ORNL is developing advanced austenitic alloys for use in fluidized-bed and pulverized coal combustion power plants, with the objective of modifying existing alloys so as to provide the strength and corrosion resistance needed in high-temperature, high-pressure, second-generation power plants. Intermetallic alloys, primarily iron aluminides, are being developed for applications in which superior oxidation and sulfidation resistance and strength are required. Improved room-temperature ductility, resistance to hydrogen embrittlement, and fabricability will continue to be emphasized in the next several years. Oxide dispersions with iron aluminides are being investigated for improved high-temperature alloy strength.

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. An understanding of the properties and characteristics of oxide scales is evolving.

ORNL is committed to transferring the technology developed in the Fossil Energy Materials Program to industry and to others in the fossil energy community. A number of licenses and CRADAs have been executed. A CRADA with Cummins Engine Company involves direct-energy-regenerated particulate trap technology. Two CRADAs with ABB-Combustion Engineering, Inc., are exploring cold work effects on advanced austenitic alloys and corrosion-resistant coatings using iron aluminides. A CRADA with Hoskins Manufacturing Co., a licensee, is investigating the fabricability of the lower-aluminum alloy FAPY for commercial applications.

In the EAS area, ORNL provides technical and analytical support to the Morgantown Energy Technology Center (METC) by evaluating environmental concerns related to coal R&D projects and by preparing National Environmental Policy Act (NEPA) assessments of the projects.

Growth continues in bioprocessing for coal conversion and use at the ORNL Bioprocessing Research and Development Center. Activities include the conversion of coal to useful liquid and gaseous fuels as well as the removal of heteroatoms and hazardous materials from coal, coal liquids, combustion gases, and other gaseous and liquid effluents and products. Innovative microbial and biochemical pathways for bioprocessing concepts are being investigated for use in these areas, and advanced bioreactor systems that can efficiently and economically carry out such processes are being developed. Over 40% of some types of coal can be converted to liquids by reduction processes catalyzed by modified enzymes that can operate in organic solvents. Other biocatalytic systems are being investigated to remove organically bound sulfur that contaminates coal-derived liquids. Cooperative research with academic and industrial researchers is being conducted in almost all phases of this bioprocessing effort.

Molecular hydrogen is a valuable chemical feedstock for the liquefaction of coal and for hydrocracking and hydrotreating of petroleum. Virtually all hydrogen used in current processes is itself derived from natural gas. Current research is focused on the production of molecular hydrogen via photosynthetic water splitting; ORNL staff have discovered that a mutant of *Chlamydomonas reinhardtii* is capable of sustained simultaneous photoevolution of molecular hydrogen and oxygen by way of only a single light system, Photosystem II. This result has important implications for the net thermodynamic conversion efficiencies of light energy into chemical energy. This research also receives support from the Office of Energy Efficiency and Renewable Energy (DOE-EE).

Coal combustion research includes a CRADA project with Babcock & Wilcox on the analysis of fluidized-bed combustion data for deterministic chaos and METC-funded collaborations with other university and industrial partners to develop improved fossil energy process control through application of chaos theory.

Gas—AB

The development of advanced turbine systems for power generation is the objective of a program jointly sponsored by DOE-FE and DOE-EE. The objective of the Advanced Turbine System (ATS) Program is to develop ultrahigh-efficiency ($\geq 60\%$ in a combined

cycle), environmentally superior, cost-competitive gas turbine systems for utility and industrial applications. A supporting element of the ATS Program is the Materials/Manufacturing Technologies Task, which is being coordinated by ORNL to address critical materials and manufacturing issues for both industrial and utility gas turbines.

Petroleum—AC

A bioprocessing R&D program for treating petroleum, petroleum-derived products, and effluent streams has been initiated. The most significant effort is a cooperative research program for the removal of sulfur, nitrogen, and other contaminants from crude petroleum and other refinery streams. This program involves six CRADAs with several major oil companies and bioprocessing firms through the Petroleum Environmental Research Forum, a collaborative effort on the part of these companies. In addition, programs are being developed in the area of bioremediation for petroleum industry sites. A CRADA is being negotiated to extend advanced membrane technology to the separation of hydrogen from various refinery gas streams.

Innovative Clean Coal Technology—AZ

Work on the Clean Coal Technology Program (CCTP) includes support in the areas of environment and materials. The CCTP is jointly funded by DOE and industrial organizations. All five planned solicitations have been completed by DOE. An important part of ORNL's involvement in the CCTP is environmental technical support to the METC in the preparation of NEPA assessments of site-specific projects. Materials failure analyses (critical to the success of clean coal technologies) continue to be conducted for the PETC.

Strategic Petroleum Reserve—SA

ORNL provides assistance to the Strategic Petroleum Reserve Program in the development of models for planning the capacity and management of the Strategic Petroleum Reserve and for analyzing the oil market. A variety of analytical studies using these models have been completed.

5.1.2.3 • Energy Information Administration

ORNL will continue its support of the Energy Information Administration (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 new developments in the following areas of expertise:

- energy, environmental, and economic modeling,
- information systems development,
- creative file structures and maintenance,
- artificial intelligence and expert systems,
- development of an international energy database through the ORNL-U.S. Agency for International Development program (see Sect. 5.2.1.8), and
- a growing number of analyses of technological change.

A National Energy Information System would provide a coordinated approach and a center of responsibility by which the objectives and technical needs of the EIA may be met. Funding for future years is expected to be stable in real dollars.

5.1.2.4 • Power Marketing Administrations

Bonneville Power Administration

ORNL's Energy Division conducts program evaluation research for the Bonneville Power Administration's Office of Energy Resources. Bonneville has operated a Residential Weatherization Program since 1981. ORNL investigates 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 extend its leadership in the fields of artificial intelligence and power systems by developing a system to monitor Bonneville's substation equipment in real time to support reliability-centered maintenance.

The ORNL Environmental Sciences Division provides technical support to Bonneville in evaluating and mitigating the effects of Bonneville's operations on fish populations.

5.1.3 • National Security and Environmental Management Programs

5.1.3.1 • Office of Defense Programs

Weapons Activities—GB

Radiation Shielding Information Center • The Radiation Shielding Information Center provides in-depth coverage of the radiation transport field and serves the needs of a variety of disciplines on an international basis. See Sect. 5.1.6.2 for additional information.

Technology Transfer Initiative • The objective of the Technology Transfer Initiative (TTI) is to conduct R&D that will benefit both programs sponsored by the Office of Defense Programs (DOE-DP) and the private sector. ORNL is engaged in a number of CRADA projects in collaboration with the Oak Ridge Y-12 Plant, focusing on manufacturing. Project teams are made up of staff from ORNL and Y-12 in roughly equal numbers, with leadership provided by the organization with the critical elements for the technology development and transfer process.

A CRADA project with important implications for high-performance computing is directed toward the development of the High-Performance Storage System (HPSS). The goal is a network-centered system capable of parallel data transfers at rates in the gigabyte per second range. The HPSS project is a closely linked effort of Los Alamos National Laboratory (LANL), Lawrence Livermore National Laboratory (LLNL), Sandia National Laboratories (SNL), and ORNL/Y-12 with industrial partner IBM Federal. Additional institutions are now joining this development project.

As part of the TTI, ORNL operates the Ultraprecision Manufacturing Technology Center, which is dedicated to developing and validating manufacturing processes that can be used to produce affordable, high-quality components. Technical areas of concentration include precision turning, ductile grinding, ion beam milling, on-process characterization, mechanical design and analysis, and related efficient manufacturing operations. This center is a DOE Deployment/User Facility, where participants from industry, universities, and

government perform cooperative, hands-on activities. This concept makes it possible for the private sector to reap the benefits of new technology without incurring the time, expense, and risk of the "trial-and-error" approach to improving manufacturing processes. The Ultraprecision Manufacturing Technology Center is part of the Oak Ridge Centers for Manufacturing Technology (see Sect. 5.1.7.2).

The ORNL Office of Computing and Network Management coordinated ORNL's participation on the DOE-DP Technology Area Coordinating Team for Computing Architecture and Applications. This team identified several priority areas: gigabit network technology, materials by computer design, automotive design and manufacturing, software tools, and banking.

The Office of Computing and Network Management also coordinates the distribution of some of the DOE-DP block grants now being awarded. The first such grant is supporting work in collaboration with the gas and oil industry, focusing on National Information Infrastructure (NII) technologies. The goal of the Gas and Oil NII Testbed is to apply DOE's computational research and system integration abilities in advanced information technologies to U.S. industry issues. In cooperation with LANL, LLNL, and SNL, ORNL and Y-12 are researching dual-use infrastructure needs applicable to both the defense industry and the geographically distributed gas and oil industry. This project consists of multilaboratory development of a Synthetic Seismic Dataset for standardized benchmarking, forming the basis for a computing and communications testbed with the gas and oil industry. Additional projects address network infrastructure needs including:

- data-distributed visualization and computational steering (as an acceptable front end to massively parallel computing environments),
- virtual reality (interactive immersion environments for scientific investigation and communication),
- remote collaboration environments (to allow geographically distributed scientists and managers access to the same "objects" on their workstations),
- network applications to benchmark the application performance of these NII tools, and
- on-line information services (to provide access to information within this project).

Some interactivity between these projects will occur as the tools developed in one project will be applied in another.

Materials Production—GE

The materials production program includes the ^{252}Cf Industrial Sales/Loan Program (co-sponsored by the Office of Energy Research and discussed in Sect. 5.1.1.1), the Mark 42 Processing Program, and the ^{233}U Storage and Distribution Program.

The Mark 42 Processing Program involves the recovery and purification of transuranium element isotopes (^{242}Pu , ^{243}Am , and ^{244}Cm) from Mark 42 targets that were previously irradiated at the Savannah River Site and segmented at the Pacific Northwest National Laboratory. The Mark 42 targets are processed to recover light transuranium element isotopes for use in weapons diagnostics at LANL and LLNL. Targets are processed at the rate of about 1 target every 18 months. Processing began in 1991; ten targets have been transferred to the ORNL Radiochemical Engineering Development Center for storage and processing.

Shielded, safeguarded storage and some distribution of ^{233}U continue in the Radiochemical Development Facility (Building 3019) at ORNL. Equipment for processing ^{233}U has been in standby since 1989. Plans are being developed to improve the condition of the

aging facility to ensure safe, long-term storage and distribution of ^{233}U . An initiative for ^{238}Pu production at ORNL, which would involve the use of this facility for ^{237}Np storage, is discussed in Sect. 5.1.1.2.

5.1.3.2 • Office of Environmental Management

ORNL receives funding from the Office of Environmental Management (DOE-EM) for (1) activities aimed at correcting existing problems, preventing future problems, managing currently generated and legacy waste, and minimizing waste generation at the ORNL site, as described in Sect. 6.3, and (2) R&D and technical support for addressing environmental management problems, principally at DOE sites, with increasing emphasis on technology transfer to the public and private sectors. Much of this activity is conducted by the ORNL Environmental Sciences Division, the ORNL Chemical Technology Division, the Center for Risk Management in ORNL's Health Sciences Research Division, and the Center for Environmental Technology, in which ORNL plays an integral role. The two centers are discussed in Sect. 5.1.7.

Environmental Restoration

Because of the Oak Ridge geologic setting, the high rainfall, the active groundwater and surface water systems, the history of waste disposal, and nearby population centers, the environmental restoration challenges at Oak Ridge are the greatest within the DOE complex.

The Environmental Restoration Program effort at ORNL integrates activities supporting transition of inactive facilities for decontamination and release or for demolition with remedial actions for contaminated sites. The program's primary goal is protecting human health and the environment. The ORNL Environmental Restoration Program teams with the Waste Management and Remedial Action Division to provide a comprehensive environmental management program for the ORNL site. The program takes full advantage of the scientific and technical resources at ORNL to meet the local environmental restoration challenges, and it strives to fundamentally improve the process of environmental restoration. Innovative approaches are developed and used to focus and streamline decision making to provide safe and cost-effective risk reduction. The program supports the development and demonstration of technologies for characterization and remediation of sites and facilities, and it collaborates with efforts supported by the DOE Office of Technology Development to demonstrate and/or employ new tools in the remediation process. ORNL scientists and engineers also provide technical support to environmental restoration programs at the Oak Ridge Y-12 Plant, the Oak Ridge K-25 Site, and DOE facilities at Paducah, Kentucky, and Portsmouth, Ohio.

In conjunction with the Surplus Facilities Management Program (SFMP), the ORNL Environmental Restoration decontamination and decommissioning (D&D) program provides surveillance and maintenance to ensure the safety of DOE sites awaiting decontamination or remediation, planning of the orderly decommissioning and stabilization of sites and facilities, and a program for final disposition. Activities related to cleanup at the ORNL site are described in Sect. 6.2.

ORNL provides support for DOE-EM activities beyond the boundaries of the ORNL site via several remedial action projects (RAPs). Major ORNL activities in RAPs include conducting radiological surveys on private properties near inactive mill tailings sites [Uranium Mill Tailings Remedial Action Project (UMTRAP)] and at facilities that were

formerly used under contract with the Atomic Energy Commission [Formerly Utilized Sites Remedial Action Project (FUSRAP)]. The radiological status of sites involved in DOE's RAPs is identified, characterized, and verified to provide a basis for reducing the health impacts of fuel cycle activities. Advancement of the state of the art in equipment and methodology is an integral part of this work.

In support of these activities, ORNL maintains an office in Grand Junction, Colorado. The Grand Junction office leads an effort to identify properties near 24 inactive uranium mill sites and recommend their inclusion in UMTRAP. Most of the inclusion surveys have been completed. The Grand Junction office is also responsible for verifying the adequacy of remedial actions taken to address contamination in excess of relevant Environmental Protection Agency (EPA) criteria and DOE guidelines at UMTRAP sites and at western sites accepted into the SFMP. An ORNL group based in Oak Ridge carries out the equivalent functions for radiologically contaminated sites in the FUSRAP and at eastern sites accepted into the SFMP.

Funding for FUSRAP is expected to remain level. SFMP funding is expected to increase as the level of decommissioning effort at federal facilities increases. ORNL will verify that these facilities are decontaminated in accordance with established DOE guidelines.

New approaches, processes, and technologies are required to tackle many of the pressing environmental restoration problems facing DOE. R&D coupled with demonstration, testing, and evaluation (RDDT&E) is critical to fostering cost-effective solutions to these problems. An important part of the ORNL effort is directed toward RDDT&E in direct support of real problems at DOE sites.

If decontaminated facilities are to be released for unrestricted use, well-documented clearance criteria will be needed. Establishing these criteria will require a definition of the relationship between residual surface contamination and the absorbed dose resulting from skin absorption, ingestion, or inhalation of dust or vapors from surfaces. Staff members in the ORNL Health Sciences Research Division are applying their expertise in radiological surveying and indoor air quality to make measurements and refine models that will be used to develop this definition.

The Energy Systems Groundwater Program Office (GWPO) promotes consistency among groundwater activities at the DOE facilities managed by Energy Systems and acts as a focal point for technical and programmatic interactions with the public and with state and federal regulatory agencies. Groundwater protection program coordinators at each site are responsible for oversight of all groundwater activities at their sites and for facilitating integration of requirements of the compliance and environmental restoration groundwater programs. The Oak Ridge Hydrology Support Program provides technical support to the GWPO to assist in achieving technical consistency and defensibility across the site programs and to facilitate the sharing of lessons learned. Both of these programs are managed through ORNL's Environmental Sciences Division.

Waste Management

Waste management activities at ORNL are discussed in Sect. 6.3. These activities include the operation of 119 facilities, ongoing upgrades of ORNL waste management facilities needed to support the programmatic missions of DOE, management of wastes produced by previous operations and research, and waste minimization activities.

Technology Development

The DOE-EM Office of Technology Development is charged with developing and demonstrating new technologies for dealing with DOE's environmental management problems. The ORNL Office of Environmental Technology Development, one of five offices in the Center for Environmental Technology (see Sect. 5.1.7.2), manages a diverse program of technology development to address these problems. The program involves developing new technologies and demonstrating or modifying existing techniques to ensure application of the most cost-effective and technologically advanced remediation and waste management methods. This work is conducted at ORNL, the Oak Ridge Y-12 Plant, the Oak Ridge K-25 Site, and, to a lesser extent, DOE's Paducah and Portsmouth facilities. The technologies being developed are shared among DOE sites and with the private sector for use in solving similar environmental problems. Program components include:

- **Treatability**—in situ immobilization, thermal treatment, and/or advanced oxidation methods for the treatment of soils contaminated with volatile organic compounds (VOCs) and low levels of radioactive substances; in situ vitrification to instantly destroy many hazardous components and immobilize the remainder in a glass or slag matrix.
- **Characterization**—modeling of hydrologic systems; advanced field measurement and sensing methods; improved systems for data collection, analysis, management, and display; biomarker and biosensor instrumentation to monitor contaminant behavior and response to remediation strategies using improved, less costly, analytical means in situ and in real time; and field-oriented methods that allow characterization of sites and contaminants with minimal cost, health, and safety impact.
- **Bioremediation**—microorganisms that can fix, degrade, detoxify, or accumulate selected organic compounds [e.g., tetrachloroethylene, trichloroethylene, polychlorinated biphenyls (PCBs)] and inorganic materials (e.g., uranium, strontium, cesium, lead, cadmium, copper) in situ or in process.
- **Robotics**—robotic systems and remote technology that can enhance environmental restoration and waste management operations by removing workers from radioactive, hazardous, and mixed waste; increasing speed and productivity of characterization and remediation; and reducing life-cycle costs.
- **D&D**—decontamination and decommissioning of metals and concrete to assist in the decommissioning of formerly utilized facilities.
- **Waste minimization**—action that minimizes the volume or toxicity of waste by recycling, recovery, and reuse of materials; source substitution; and process modification to reduce the production of radioactive, hazardous and mixed wastes at the generation point.
- **Transportation**—database evaluation and site verification to develop an understanding of site-specific needs; systems engineering to evaluate methods of meeting transportation requirements for a reasonable number of applications, including hazardous and mixed waste remediation efforts; risk assessment and regulatory support to systematically define the requirements for on-site and off-site transport of hazardous and mixed waste; and base technology development to evaluate the effect of hazardous substances on packaging components.
- **Technology transfer**—facilitation of the transfer of technologies that could improve program and operational effectiveness, reduce costs, and save time, among federal agencies, industry, academia, and the international community.

Although some of the technologies mentioned here are currently developed, much more refinement and advancement are necessary for their cost-effective application to

increasingly challenging waste problems. Significant industrial involvement is expected, especially during the demonstration phase of the technologies; this will require an efficient transfer of new technologies for application both to and from the DOE facilities. In an effort to increase the number of qualified scientists and engineers, this program also sponsors joint research projects with universities and minority institutions to encourage students to study in fields applicable to environmental restoration and waste management.

Significant accomplishments include the deployment of the direct sampling ion trap mass spectrometer at the Oak Ridge, Savannah River, and Hanford sites for real-time monitoring of VOCs; demonstration of remote excavation of buried waste; and demonstration of alternating current swing-free crane robotic technology. Funding is anticipated to remain stable over the planning period.

In other work for the Office of Technology Development, staff from the ORNL Health Sciences Research Division are conducting projects involving the development or demonstration of portable techniques for detecting organic chemical components at or near hazardous waste sites. Derivative ultraviolet absorption spectroscopy using fiber-optic cables can be used to detect benzene, gasoline, and other contaminants in groundwater with a very rapid response (<1 min) using rugged, lightweight instruments. Spectrochemical techniques are expected to be equally successful in the detection of trace amounts of chlorinated hydrocarbons in soil and groundwater.

Quality Assurance and Quality Control

The ORNL Environmental Sciences Division will assist the Office of Environmental Activities in its EM-wide document review, guidance, training, and auditing functions.

Compliance and Program Coordination

For the Office of Transportation, Emergency Management, and Analytical Services, ORNL 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. Funding is expected to remain stable.

5.1.3.3 • Office of Fissile Materials Disposition

Fissile Materials Disposition—GA

With the end of the Cold War, major reductions in nuclear weapon stockpiles are creating significant inventories of nuclear material that are excess to military needs. Long-term nuclear weapons concerns and environmental, safety, and health risks posed by these inventories pose a significant challenge to the United States and to other countries. DOE has launched a project to evaluate and implement strategies for disposition of U.S. excess weapons-capable materials inventories such as plutonium (50 metric tons), highly enriched uranium (HEU) (>50 metric tons), and ^{233}U (>1 metric ton). Near-term options for storage and disposition and ultimate disposition strategies must be addressed.

A program is under way at ORNL to support the Office of Fissile Materials Disposition (DOE-MD). ORNL is DOE's lead laboratory for reactor-based technologies for fissioning surplus plutonium. ORNL also has the lead for all technologies associated with storage and disposition of ^{233}U and minor actinides (transuranic elements other than plutonium). In these roles, ORNL will have cradle-to-grave responsibility for leading the evaluation and implementation of U.S. strategies for reducing the inherent proliferation potential of these DOE materials. Additionally, ORNL is being funded to develop an advanced vitrification technology for plutonium and is supporting Lawrence Livermore National Laboratory (LLNL), Los Alamos National Laboratory (LANL), and Sandia National Laboratories in the development and assessment of other plutonium handling technologies.

Evaluation activities are expected to result in a decision in FY 1996 on which technologies for disposition of plutonium, HEU, and ^{233}U will be supported for future evaluation and implementation. Activities in FY 1997–FY 2001 are expected to include R&D on enabling technologies and the start of implementation of the disposition options.

Reactor-Based Disposition of Plutonium • ORNL will lead the DOE effort to evaluate and characterize for a programmatic environmental impact statement (PEIS) the reactor options for converting plutonium into spent fuel. Reactor options to be evaluated include mixed-oxide (MOX) fuel in existing or partially completed U.S. light-water reactors (LWRs), MOX fuel in CANDUs, MOX fuel in newly constructed advanced LWRs (ALWRs), or use of Euratom MOX fuel fabrication facilities and reactors. Factors to be addressed include performance, environmental impacts, cost, timeliness, and technical risk.

Implementing R&D, to be coordinated with commercial reactor vendors, will include core design and dynamic reactor controls studies, performance of lead test assembly qualification, examination of the irradiation performance of the Zircaloy-clad MOX fuel, and evaluation of the impact of lower delayed-neutron levels and faster neutronic time scales on the progression of possible severe reactor accidents and source term dynamics and energetics.

A more basic R&D program will be conducted on use of so-called "deep burn" reactor options for disposition of plutonium with nonfertile fuels. Technologies to be investigated include graphite fuel in a modular helium reactor, dedicated $\text{LiF/BeF}_2/\text{PuF}$ molten salt reactors, and the plutonium-based graphite particle bed reactor.

Collaborative Studies with Russian Institutes • Under the auspices of DOE, ORNL will conduct collaborative studies with Russian institutes on reactor-based options for disposition of Russian plutonium. Three collaborative programs on plutonium disposition will be conducted: one with the I. V. Kurchatov Institute concerning the use of LWRs, VVERs, and CANDUs; one with the Physical Engineering Institute, Obninsk, on the use of fast reactors such as the BN-800; and one with the Kurchatov Institute concerning the use of high-temperature gas-cooled reactors using nonfertile PuO_2 fuel.

^{233}U and Minor Actinides • ORNL will lead a multilaboratory effort to characterize inventories of ^{233}U and other minor actinides and to identify and evaluate options for reducing their proliferation resistance and for their eventual disposal. ORNL will be supported by LANL, LLNL, and the Idaho National Engineering Laboratory in this activity. For ^{233}U , emphasis will be on defining blend-down technologies, flowsheets, and component designs with the objective of making the ^{233}U incapable of weapons use ($<12\%$ ^{233}U). Blend-down of ^{233}U is different from blending of HEU because of the different chemical forms of the ^{233}U and because the downblended ^{233}U product will be waste rather than LWR fuel. Options for direct disposition of ^{233}U and minor actinides to the Waste Isolation Pilot Plant or other deep geologic waste facilities will be examined. Methods for co-vitrifying the

fissile materials with existing stocks of DOE high-level waste will also be examined. Studies of ^{233}U storage will center on technologies for international inspectability and container integrity inspectability of stored ^{233}U canisters.

GMODS Vitrification of Plutonium • ORNL will develop and characterize a novel technology, glass material oxidation and dissolution system (GMODS), for vitrification of metallic plutonium without the currently required steps for converting the plutonium into an oxide. The GMODS technology appears to be particularly attractive for the initial dissolution into borosilicate glass of plutonium scrap and residues. Potential benefits of GMODS include lower cost, reduced environmental impacts, and improved international inspectability of plutonium operations. During FY 1995, the GMODS technology was selected from a field of 36 technologies as one of 9 technologies to be evaluated as part of the plutonium disposition PEIS.

Accelerator-Based Conversion of Plutonium • R&D on accelerator-based options is desirable to maintain long-term options for nearly complete destruction of plutonium should that prove to be eventually desirable; however, accelerator-based conversion technologies are not being considered as an alternative for the near-term mission of disposing of the first 50 metric tons of weapons-grade plutonium. ORNL will support LANL and Brookhaven National Laboratory (BNL) in the development of advanced technologies for the accelerator-based fissioning of plutonium. ORNL will lead the development of plutonium-based graphite fuels in the BNL technology program and will develop plutonium-based molten salt technology, chemistry, and materials of construction in the LANL-led option. ORNL will also conduct a series of system analyses and perform preconceptual facility design for the nonaccelerator parts of the systems.

Transportation Technologies • ORNL will define transportation technologies and evaluate transportation operations and risks for all transportation legs in all program options that involve low-level or high-level radioactive materials. The scope of this task will include transportation of spent MOX fuel in reactor operations, transportation of glass logs with plutonium and high-level waste for immobilization options, and shipments of cesium capsules and low-level waste in several options.

Economic Analysis/Decision Analysis • ORNL will define the economic guidelines and perform life cycle cost analysis for all of the disposition options to be evaluated by DOE. In addition, the ORNL program manager will serve as a member of the DOE Screening Committee for providing supporting assessments for DOE decisions on plutonium, HEU, ^{233}U , and minor actinide disposition. ORNL will also support various DOE public outreach activities by providing technical experts for interfacing with the public and with industrial stakeholders.

Rapid changes in the international nuclear materials situation continue to affect U.S. policies, priorities and strategies for fissile materials disposition. ORNL will continue to seek new roles and to investigate applications of new technologies to respond to these changing circumstances.

5.1.3.4 • Office of Civilian Radioactive Waste Management

Nuclear Waste Fund—DB

ORNL's work in support of the DOE Office of Civilian Radioactive Waste Management (OCRWM) is funded by the Nuclear Waste Fund (program DB) and through work for others (WFO). ORNL's current activities involve waste and facility information and

databases (DB03); systems engineering, environmental technical assistance, and strategic and contingency planning (DB09); and transportation and systems engineering (WFO). OCRWM has transferred many of its activities to its management and operating contractor. The transportation and systems engineering work in the WFO area is being performed under a memorandum purchase order arrangement with this contractor. Funding is expected to remain level during the planning period.

Work in the DB03 area involves support for waste and facility information and databases, including completion of the Facility Interface Capability Assessment (FICA) work, continuing support of the Integrated Data Base (IDB), and support of transportation-related institutional activities. The FICA has resulted in the development of a global assessment of the ability of the nation's 122 reactors to accommodate various spent fuel shipping casks. The IDB is jointly funded and provides a comprehensive, top-level perspective on the wastes that must be handled by DOE in the future; it contains DOE's official spent fuel and radioactive waste inventories and projections through 2020.

Transportation support involves studying the development of support systems, assessing systems alternatives, and supporting the testing of a tractor for pulling a legal-weight highway cask system. One major area will be the continued development of site-specific services planning documents for defining specific logistical interfaces between cask systems and reactor handling facilities. In addition, support will be provided in assessing the development of the multipurpose container system design concepts, in the development and maintenance of computer models needed by the OCRWM transportation project, and in supporting a case before the Nuclear Regulatory Commission for allowing burnup credit in cask designs.

Systems engineering efforts in both the DB09 and WFO areas are focused primarily on improved applications of the ORIGEN2 code used for projecting radionuclide inventories and on verifications and validation. Environmental technical assistance in the DB09 area involves continuing support in evaluating environmental aspects of the high-level waste management program. Strategic and contingency planning provides support in preparing and evaluating plans and strategy reviews of the OCRWM program.

5.1.4 • Environment, Safety, and Health

Office of Environment, Safety, and Health

Work is performed at ORNL for the Office of Environment, Safety, and Health (DOE-EH) by nearly a dozen organizations spread throughout the Laboratory structure. This work is coordinated by a program manager for all R&D and technical support activities funded by DOE-EH. The program manager reports directly to the Laboratory Associate Director for Life Sciences and Environmental Technologies. This focal point for communication and coordination provides an effective and responsive interface for the matrix of principal investigators and customers.

Environment—HA

Technical support activities for DOE-EH 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 technical support to the Office of Environmental Policy and Assistance. 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 (see Sect. 5.1.6.2). ORNL has provided substantial support for training in environmental laws and regulations, and the development and implementation of training courses in these areas for DOE and its contractors will continue as requested. Efforts will focus on subjects important to DOE's environmental restoration program, such as Resource Conservation and Recovery Act (RCRA) closures, applicable or relevant and appropriate requirements under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), and the Natural Resources Damage Assessment process.

ORNL also provides technical support to the Office of Environmental Policy and Assistance in standards and procedures development, calculational model validations, risk assessment, and radiation protection requirements. The Laboratory is developing a radiological survey procedures manual that provides detailed specifications for measurement and assessment of radiological environmental pollutants. The manual will serve as the basis for radiological surveys at DOE and contractor facilities. ORNL staff also provide support to DOE's Risk-Based Standards Working Group, which is developing guidance on health and environmental risk assessments performed at DOE facilities.

ORNL has the capability to conduct large-scale hydrogeological and environmental characterization activities that are essential to addressing the contamination problems at many DOE sites. Increasing interaction with regulatory agencies is creating the need for a uniform, efficient, and well-organized approach to the development and initiation of site-wide characterization studies. ORNL plans 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 the sites. ORNL technical support in emergency response R&D is available.

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

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

Safety and Quality Assurance • ORNL provides technical and administrative support for the ES&H Business Management and Budgeting Plan (formerly the Five-Year Plan) administered by DOE. Contributions include participating on the development team for the plan, developing a risk-based model to prioritize ES&H issues and projects, and training facility and field office personnel at DOE sites across the country.

The Laboratory provides technical and management assistance to DOE for several occupational safety and health (OSH) tasks: (1) development of new approaches to OSH program evaluation and management, (2) development of an OSH handbook for DOE contractors that includes "how to" information for contractors and for DOE staff and line organizations, (3) conduct of a "benchmarking" program of sharing notably effective OSH programs among DOE contractors, (4) development of response capability for a toll-free telephone

number receiving requests for interpretations of OSH regulations, (5) establishment of DOE's equivalent to the Occupational Safety and Health Administration's Voluntary Protection Program, (6) implementation of an electrical safety program, and (7) ensuring that the safety and the health of workers and the public are protected during all DOE environmental management activities.

Transportation and Packaging Safety • Work at ORNL for the DOE-EH Office of Facility Safety Analysis includes the Packaging and Transportation Program, which provides technical and management support for the hazardous materials-related transportation safety activities and responsibilities of DOE-EH. Oversight assistance is supplied to DOE by providing technical support and staffing of the assessment teams for DOE-EH site representatives' packaging and transportation performance assessments, the technical assistance program, and the packaging evaluation program. Assistance is also provided in analyzing the packaging and transportation safety implications of reports submitted by contractors to the Occurrence Reporting and Processing System.

ORNL has also been responsible for drafting a series of DOE Orders on the safety of the transportation and packaging of hazardous materials, explosives classification, on-site transport, and motor vehicle safety. Other support from ORNL in the policy and guidance area includes continued work on a packaging design guide and the provision of technical and management support to various national and international guidance and standard-setting committees. Technical assistance to DOE includes technical reviews, preparation of papers, participation in programs, and preparation of management plans.

Support to the Transportation and Packaging Safety Division also encompasses maintenance and enhancement of the Standardized Computer Analysis for Licensing Evaluation computational system, SCALE. SCALE is used throughout the world in performing safety evaluations in the areas of nuclear criticality safety, radiation protection, radioactive material characterization, and heat transfer. Upgrades and corrections to the system are available to users through the Radiation Shielding Information Center at ORNL (see Sect. 5.1.6.2). A SCALE Users Training Course sponsored by the Transportation and Packaging Safety Division is conducted by project staff at ORNL. Course attendees include representatives from DOE, the Nuclear Regulatory Commission, national laboratories, and industry, plus a number of international participants.

Biostatistical Support for Health Studies • ORNL continues to provide the Deputy Assistant Secretary for Health Studies with statistical support for programs in epidemiologic surveillance and occupational medicine. Statistical methods that are being developed to describe and evaluate illness and injury event data will be used by DOE's Epidemiologic Surveillance System, which will monitor the health of the work force at all DOE sites and will be used to identify health hazards in the work place. The Office of Occupational Medicine and Medical Surveillance is conducting a follow-up study of beryllium workers at the Oak Ridge Y-12 Plant. The beryllium lymphocyte proliferation test is being used as part of a screening procedure to identify individuals who may have chronic beryllium disease. Statistical methods that will facilitate the evaluation of this test are being developed. ORNL provides general biostatistical support to the Office of Epidemiologic Studies for the planning, analysis, and interpretation of studies related to health and environmental issues.

Nuclear Safety Policy and Standards—HP

DOE Technical Standards Program • Since the late 1960s, ORNL has led in the management and overall conduct of standards development efforts, first for the Atomic Energy Commission and now for DOE. In this position, ORNL assisted DOE in establishing the program procedures and guidance for all participating DOE and DOE contractor organizations to implement DOE's standards policy. ORNL responsibilities for the DOE Technical Standards Program are

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

DOE Performance Indicator Program • DOE, in a manner similar to the commercial nuclear industry, considers that facilities with good performance, as measured by an overall set of performance indicators, are generally recognized as well-managed facilities. The objective of DOE's performance indicator program is to collect data on key performance indicators and to have line management analyze and trend the data. ORNL compiles and prepares quarterly summaries based on quarterly reports received from the senior officials in the DOE performance indicator program and performs special analyses of these data as requested. In addition, ORNL provides assistance in conducting workshops on the program for DOE and contractor personnel and evaluating sources of performance indicator data.

Nuclear Criticality Safety Analytic Methods Resources Center • ORNL develops and maintains state-of-the-art analytic methods for determining nuclear criticality safety. These methods include the KENO software, which has been, in successive versions, the industry standard for this application for the past 25 years. KENO is incorporated in the SCALE system and is distributed by the Radiation Shielding Information Center (see Sect. 5.1.6.2).

5.1.5 • Other DOE Programs

ORNL provides support to other DOE offices and installations, including the Office of Policy, Planning and Program Evaluation; the Office of the Associate Deputy Secretary for Field Management; the Federal Energy Regulatory Commission; other DOE contractors and operations offices, and other Energy Systems sites.

5.1.5.1 • Assistant Secretary for Policy

Policy Planning and Analysis—PE

Work for the Assistant Secretary for Policy 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, fuel economy standards for automobiles and light trucks, and energy options for developing nations. Research will continue on the effects of clean fuels and reformulated gasoline on the energy industry, consumers, and the environment. ORNL anticipates continuing work in support of DOE's role in assisting the Council on Environmental Quality in the development of a national strategy and plan for reporting long-term environmental trends. Additional support is provided in the area of regulatory analyses for hydropower development and environmental compliance issues.

ORNL supports the Office of Environmental Analysis and Sustainable Development in developing energy resource assessment models and providing background research for various energy and environmental policy issues. This office 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, studies of international developments in global climate change, research on the physical and ecological effects of climate change, research on the economic valuation of energy-related environmental impacts, and studies of the impacts of environmental policies on electric utilities. A major effort is in progress to analyze fuel cycles and to provide estimates of (1) the physical impacts on environmental resources, including human health and safety, and (2) costs and resulting potential effects on market prices for major fuels.

ORNL also provides support on hydropower issues (e.g., by studying the feasibility of a hydropower environmental mitigation information analysis system). If DOE continues to support this concept, additional long-term funding may be received.

ORNL is actively involved in developing a DOE program related to the energy needs of developing nations. The Assisting the Deployment of Energy Practices and Technologies (ADEPT) Program includes needs studies, technical information, institution building, training, technology adaptation, and technology demonstration. ORNL roles include project activities and program support. In addition, ORNL is supporting the development of an Energy Efficiency Strategy Assistance Program.

5.1.5.2 • Associate Deputy Secretary for Field Management

In-House Energy Management—WB

ORNL is conducting energy management studies in Laboratory facilities to identify retrofit projects that will allow achievement of the energy consumption and efficiency goals established by DOE and reflected in ORNL's ten-year energy plan. The goals in the plan are addressed through a comprehensive Energy Management Program. The program's elements integrate energy conservation activities specific to ORNL's buildings, equipment, processes, and vehicles. Heating, ventilation, and air conditioning systems are being upgraded to improve their efficiency.

5.1.5.3 • Federal Energy Regulatory Commission—VR

ORNL provides assistance to the Federal Energy Regulatory Commission (FERC) in two major areas: (1) environmental, economic, and engineering assessments that support licensing of nonfederal hydroelectric projects, and (2) additional studies related to compliance with FERC license conditions or other environmental regulations at existing projects. Ongoing work includes development of a site-specific NEPA document on the Tuolumne River in California, where competing water uses are being evaluated, and studies in the state of Washington, where 17 small-scale projects are proposed in the Skagit and Nooksack river basins, and in Montana for a nine-dam relicensing action on the upper Missouri and Madison rivers. ORNL is also supporting FERC in a programmatic study of the cumulative effects of all hydropower projects in California's Central Valley; this study is related to coordinated federal and state regulatory proceedings to solve environmental quality problems in the Sacramento–San Joaquin Delta. ORNL develops complex computer models to predict the environmental benefits and socioeconomic costs of mitigation alternatives. Issues of national importance are addressed, such as biodiversity, endangered species, and reallocation of water resources. Relicensing of existing projects has become a major effort for the FERC, and ORNL staff are working to define methods to enhance an environment that may have been affected by 50 years of hydropower operation.

5.1.5.4 • Other Programs

ORNL performs numerous small tasks, frequently on an ad hoc basis, for a number of other organizations within DOE, including the Assistant Secretary for Congressional and Intergovernmental Affairs, the Economic Regulatory Administration, DOE's Oak Ridge Operations Office, and others. These activities are distributed among the various Laboratory programs and together make up about 5% of ORNL's total funding.

Managers at Oak Ridge sites and the Portsmouth Gaseous Diffusion Plant continue to need new or better field screening tools in the assessment of environmental restoration needs at their plants. Staff from the ORNL Health Sciences Research Division field-test newly developed analytical techniques at these sites. In addition, they provide a rapid-response, field-portable, analytical capability to address unforeseen needs at these sites.

Biological monitoring continues to be an important activity for complying with National Pollutant Discharge Elimination System (NPDES) permits and demonstrating the efficacy of environmental restoration activities. The Environmental Sciences Division takes the lead in conducting and managing biological monitoring activities at all three Oak Ridge sites, at Portsmouth, and at the Paducah Gaseous Diffusion Plant.

The Knolls Atomic Power Laboratory provides support to ORNL's Computational Physics and Engineering Division for the continuing development of TORT, the Three-Dimensional Oak Ridge Transport Code. Emphasis is on developing new code features, options, and improvements that are crucial to the modeling of large, complex shield geometries. The goal of this research is to significantly reduce job execution time, central memory requirements, and input/output file size. Near-term activities include the development and implementation of iteration acceleration techniques for convergence enhancement, multitasking capabilities for operation on parallel processing computers, and code-to-code coupling technologies for "bootstrapping" calculations.

5.1.6 • Other ORNL Programs

In addition to R&D programs with direct support from a principal DOE sponsor, ORNL is engaged in a number of cross-cutting programs that support DOE's businesses and critical success factors. Two of these—reactor operations and scientific and technical information management—are described here. See Sect. 5.1.7 for existing and proposed integrated R&D efforts.

5.1.6.1 • Reactor Operations

The Research Reactors Division (RRD), which is part of the Advanced Materials, Physical, and Neutron Sciences directorate at ORNL, oversees the operation, maintenance, and support of ORNL's research reactors so that they safely, reliably, and efficiently fulfill their intended functions in isotope production, research, and training. RRD works with 11 other ORNL divisions and organizations that either conduct reactor-based research or support reactor operations. Programmatic funding support is primarily received from DOE's Office of Energy Research (DOE-ER), and oversight is provided by the Office of Nuclear Energy, Science and Technology (DOE-NE) and the Oak Ridge Operations Office (DOE-ORO).

ORNL currently operates one Category A reactor, the High Flux Isotope Reactor (HFIR). Use of HFIR is expected to continue for

- production of transplutonium isotopes,
- neutron scattering studies for materials science,
- production of high-specific-activity radioisotopes (for medicine, industry, and research),
- materials irradiation,
- gas-cooled reactor fuel studies, and
- neutron activation analysis.

Recognizing that excellence can only be achieved through continuous improvement, reactor operations staff regularly initiate enhanced methods, processes, and procedures. Improved relations with users are being emphasized by establishing a reputation for reliability; projecting and adhering to forward-looking, 60-day operating schedules using the HFIR Users Committee to resolve competing demands; enhancing user indoctrination and training; and monitoring user satisfaction.

Near-term and interim spent fuel disposition solutions are also receiving priority attention pending the determination of final disposition arrangements by DOE. The recently fabricated and certified GE-2000 shipping cask will provide part of the solution, once the moratorium on spent fuel shipping is removed by DOE. The addition of new multiple-tier spent fuel storage silo clusters in the HFIR storage pools provides another part of the solution. Four silo clusters have been installed, and additional clusters will be fabricated and installed as needs and funding warrant. For the interim period between in-pool storage and final disposition, development of the capability for on-site dry storage is being pursued.

The Category B Tower Shielding Reactor II was shut down in 1992. Efforts are under way to prepare for permanent shutdown; budgetary constraints are limiting these efforts. A shutdown plan has been prepared and submitted to DOE for approval.

Other ORNL reactors include the Bulk Shielding Reactor and the Pool Critical Assembly. A shutdown plan for the Bulk Shielding Reactor has been prepared and submitted

to DOE for approval. The reactor has been defueled, but the fuel remains in storage racks in the reactor pool. The Pool Critical Assembly is in standby status.

Several goals for Reactor Operations have been identified:

- maintaining high morale and esprit de corps among the operating staff;
- implementing "commitment to excellence" initiatives while reducing operating costs;
- taking leadership roles in the Association for Excellence in Reactor Operations Council and Working Groups;
- coordinating external audits, evaluations, reviews, and assessments to minimize their impact on operating and support staff;
- improving relationships with DOE-ER, DOE-NE, and DOE-ORO to an excellent state, as viewed by these sponsors, customers, and regulators;
- improving the productivity of people who are assigned to, or are members of, the organization;
- empowering people; and
- implementing a Total Quality Management program integrated with the existing Performance Indicators Program.

In short, the aim of the Reactor Operations organization is to earn a reputation for being DOE's best reactor management and operations contractor.

5.1.6.2 • Scientific and Technical Information Management

Scientific and technical information is a primary product of ORNL's R&D efforts. As a unique national resource, it must be managed wisely throughout the varied stages of its "life cycle" (e.g., generation, transfer, access, packaging, storage, and retrieval). Proper management enhances the value of this information as a tool for accomplishing DOE missions and increases its availability to various audiences, including U.S. industry and the general public.

ORNL has extensive scientific and technical information resources. For example, the Laboratory is home to one of the most extensive and authoritative complexes of scientific data and information analysis centers in the United States. A complex of about two dozen information analysis centers is managed by ORNL's Environmental Sciences and Health Sciences Research divisions. More than 200 textual and/or numeric databases cover various technical disciplines, in support of DOE and other customers.

ORNL plans to use its expertise and extensive investments in computing and networking technology to develop a networked information management strategy based on distributed information access. The World Wide Web (WWW) will become the information highway of choice for global communication about ORNL's research, technology, products, and services.

As a networked laboratory, ORNL plans to use the Internet and the WWW to blend its internal and external information sources into a road map that everyone can understand and will use as a valuable resource. Information dissemination on the WWW will become a natural step in the information life cycle. Information products from ORNL's information centers and databases will be distributed via WWW servers. Subscriptions to key information will be obtained to maximize the availability of information to ORNL's staff. These plans are discussed in the ORNL *Strategic Plan for Computing*, which is summarized in Sect. 7.

ORNL expects to continue collaborations with NASA, the National Oceanic and Atmospheric Administration, the U.S. Environmental Protection Agency, the Department of

Health and Human Services, and other organizations in meeting national needs for scientific and technical information. These collaborations will be structured to take advantage of new technologies for information management such as the WWW.

Life Cycle Management of Scientific and Technical Information

By using a life cycle management approach, ORNL intends to leverage the benefit of its growing scientific and technical information base as well as its investments in information resources (see Sect. 6.4.2 for information on ORNL's information resource management plans). An example is the design and implementation of a program for managing the information base for the Advanced Neutron Source (ANS) in a totally electronic environment. Substantial progress was made in management of the information for this project—that is, in ensuring that the information was planned for, budgeted, produced, processed, disseminated, and stored in useful and cost-effective ways. Since the decision to terminate funding for ANS after FY 1995, efforts have focused on preserving the project record on compact disks so that the information can be easily accessed and used by others. ORNL plans to build on the foundation of experience and lessons learned from this endeavor to strengthen its management of scientific and technical information.

In April 1995, ORNL became the first DOE site to transmit a full-text technical report encoded with Standard Generalized Markup Language (SGML) to DOE's Office of Scientific and Technical Information. These precedes by three years the DOE milestone for SGML encoding of information products.

Scientific and Technical Information Centers and Databases

Brief descriptions of selected ORNL information centers and databases are presented here.

ARM Archive • The Atmospheric Radiation Measurement (ARM) archive is storing, managing, and processing data collected for the ARM Program, part of DOE's contribution to the U.S. Global Change Research Program, and making these data available to ARM scientists and the wider science community. The ARM Program is closely integrated with the Center for Computational Sciences (CCS) and the Center for Global Environmental Studies at ORNL. The Intel Paragon supercomputers of the CCS and the massive ARM archive will be linked to allow complete, close interaction of both systems. The ARM archive in its mature state will store terabytes of data each year and will be a worldwide resource of global change information, not only for refining general circulation models but also for understanding atmospheric phenomena such as hail formation and downbursts.

The ARM archive staff are developing the data management software and acquiring the first increment of a mass storage system for the ARM archive. Significant progress has been made in development of the ARM archive. The initial version of the data reception system, which stores and retrieves files on the ORNL mass storage tape tower, and a prototype of the user interface, which allows users to directly request data files, are operational. Design work for the next version of the ARM archive is proceeding.

Carbon Dioxide Information Analysis Center • The Carbon Dioxide Information Analysis Center (CDIAC) is a fully integrated information analysis center that acquires or compiles, documents, archives, and distributes data and other information related to CO₂, other greenhouse gases, and climate in support of the U.S. Global Change Research Program. Extensive quality assurance audits are performed on databases critical to understanding

global change. CDIAC supports the extensive data and information needs of the international research, policy-making, education, and corporate communities to assist them in the evaluation of complex environmental issues associated with elevated concentrations of CO₂ and other greenhouse gases in the atmosphere. CDIAC staff identify users' needs by attending workshops, reviewing literature, and maintaining personal contact. The center obtains and evaluates data, articles, and reports for potential worldwide distribution; produces digital numeric data and computer model packages; distributes DOE reports; and produces the newsletter *CDIAC Communications* (which has a worldwide distribution of over 7500) and the *DOE Research Summary* series.

CDIAC also houses the ORNL component of the World Data Center, designated the World Data Center-A for Atmospheric Trace Gases (WDC-A). The center is a component of the World Data System, established in 1957 by the International Council of Scientific Unions to support the data needs of the geophysical community. The World Data System is a prime method of research data exchange and archiving for the international research community, with a total of 44 data centers worldwide. WDC-A was created to meet the need of the international scientific community for a system to manage critical data related to trace gas cycling and will acquire, assure the quality of, document, archive, and distribute data and information focused on the study of atmospheric trace gases, particularly those that are important to the analysis of issues for global change. Future initiatives include developing interactive data analysis systems using networked computers throughout the world.

Chemical Unit Record Estimates Data Base • To develop guidelines and limits for controlling chemical substances by a valid scientific approach, various offices within the Environmental Protection Agency (EPA) gather and evaluate information and prepare assessment reports. The Chemical Unit Record Estimates (CURE) Data Base, a comprehensive database designed and implemented by EPA's Office of Health and Environmental Assessment and ORNL, communicates this information within the agency and facilitates the chemical regulatory process.

CURE currently comprises five subfiles: a chemical dictionary, a bibliography file, an experimental data file, a central summary file, and a comment file. The chemical file lists 1900 chemicals, classified according to the structural categories developed in the EPA Genetic Toxicology Program. This unique database provides a basis for structural activity to span genetic toxicology, low-dose toxicology, and carcinogenicity.

Distributed Active Archive Center • ORNL is one of nine Distributed Active Archive Centers (DAACs) in the NASA Earth Observing System Data and Information System (EOSDIS). EOSDIS is a key component of the U.S. Global Change Research Program. The mission of the ORNL DAAC is to provide information about the earth's biogeochemical dynamics and ecology to the global change research community, policy makers, educators, and other interested persons. This information includes ground-based and remotely sensed data relating to biogeochemical dynamics; data links are provided to other DAACs. The ORNL DAAC gathers, assures the quality of, documents, archives, and distributes data and data products in support of NASA and other global change research and policy-making efforts. The DAAC also complements the ARM archive activity at ORNL, ensuring a close tie between the two largest components of the Global Change Research Program.

Environmental Mutagen Information Center • The ORNL Environmental Mutagen Information Center (EMIC) collects and analyzes experimental data from papers reporting on the evaluation of chemical agents for genotoxicity. EMIC has indexed more than 78,000 papers reporting on more than 22,000 chemicals.

These data are used in the EPA's GENE-TOX database, which provides information allowing correlation of chemical structure and genetic activity, and in the EMIC database sponsored by the EPA and the National Library of Medicine. Information from these databases is incorporated into considerations for regulatory action and is included in the publications of the International Agency for Research on Cancer.

Human Genome Management Information System • The Human Genome Management Information System (HGMIS), sponsored by DOE and the National Center for Human Genome Research at the National Institutes for Health, provides assistance for much of the DNA mapping and sequencing research at ORNL and elsewhere. HGMIS is a primary information resource for DOE's Human Genome Program, in support of the DOE Office of Health and Environmental Research role in the national effort to map and sequence the human genome.

HGMIS helps to communicate genome-related issues and research to contractors, grantees, and the public, and it provides a forum for information exchange among researchers in both the DOE Human Genome Program and the international Human Genome Project. HGMIS maintains a traveling exhibit, provides administrative support to genome-related projects, and produces workshop reports and a bimonthly newsletter, the *Human Genome News*, which is distributed both in hard copy and electronically on the Internet. Also available electronically is a primer on molecular genetics prepared by HGMIS staff. A textual database of information on the human genome is being developed.

ORNL Environmental Restoration Data Management Program • The ORNL Environmental Restoration Data Management Program (ERDMP) supports compliance with state and federal regulations mandating the collection, consolidation, and use of environmental measurements information. In coordination with the Oak Ridge Environmental Information System (OREIS) development team, the site ERDMP team has developed an implementation plan for transmitting ORNL project data to OREIS based on Federal Facilities Agreement (FFA) milestone criteria. This activity includes receiving and verifying data from environmental restoration projects, transfer of data to OREIS, verification, and change control interactions with environmental restoration projects and OREIS. The ERDMP team also works with the Environmental Restoration Data Quality Program to review the *Central Environmental Restoration Data Management Plan* (ES/ER/TM-88, Martin Marietta Energy Systems, Inc.) and to ensure its implementation for all site projects. These coordination efforts are essential in streamlining common data management business practices at ORNL and in maintaining the highest integrity of the data products used in programmatic decision making for environmental restoration.

The ERDMP team interacts with environmental restoration project staff to assist in the preparation and review of contract activities, the development of data management plan documentation, and readiness review tasks. In addition, the ERDMP oversees data acquisition, integration, and custodial activities for environmental restoration projects. To support project management and subcontractor staff, the ERDMP team is conducting an inventory of all environmental attribute and graphical data processed and maintained at ORNL. This resource will provide the environmental restoration data user community with specific information about the types of data available and how to obtain them for project activities. The data inventory is intended to maximize the reuse of ORNL environmental data and reduce the cost incurred by obtaining unneeded data.

Radiation Shielding Information Center • The Radiation Shielding Information Center (RSIC) is a specialized information analysis center (SIAC) authorized to collect,

analyze, maintain, and distribute computer software and data sets in the areas of radiation transport and safety. RSIC follows the policy and procedure directives defined in DOE Order 1430.1D, "Scientific and Technical Information Management," June 30, 1994, and is formally recognized by DOE as an SIAC in its area of expertise.

Established in 1962, RSIC's mission is to provide in-depth coverage of the radiation transport field to meet the needs of the international shielding community. RSIC collects, organizes, evaluates and disseminates technical information involving shielding and protection from the radiation associated with fission and fusion reactors, outer space, accelerators, weapons, medical facilities, and nuclear waste management. Specific topics include

- the physics of the interaction of radiation with matter,
- radiation production and sources,
- nuclear criticality safety,
- radiation protection and shielding,
- radiation detectors and measurements,
- shielding materials properties,
- radiation waste management,
- shields and shipping cask design,
- radiation safety and assessment, and
- atmospheric dispersion and environmental dose.

RSIC receives funding from the Nuclear Regulatory Commission, the Defense Nuclear Agency, and several DOE programs.

RSIC staff members collect, maintain, analyze, and distribute technical computing software in the areas of shielding and transport; they also provide technical consultations with requesters to resolve discrepancies, assist in installation, and answer technical inquiries on radiation transport matters. RSIC also

- publishes and distributes a monthly newsletter to announce corrections, updates, or new packages as well as to notify the shielding community of items of interest,
- conducts seminars and workshops on computing methods and codes systems of particular interest to the user community,
- participates in a formal cooperative arrangement between DOE and the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development in the field of nuclear data and computer programs through international software exchange,
- works closely with the DOE Energy Science and Technology Software Center to avoid overlap and duplication of effort in software development and distribution,
- maintains computerized databases of abstracted shielding information selected for inclusion by technical analysts, and
- exchanges visits and guests assignments with shielding installations throughout the world to collect and share shielding technology for mutual benefit.

Remedial Action Program Information Center • The Remedial Action Program Information Center (RAPIC) serves the technical information needs of DOE's remedial action projects, including the Surplus Facilities Management Program, the Formerly Utilized Sites Remedial Action Project, and the Uranium Mill Tailings Remedial Action Project. RAPIC maintains the Nuclear Facility Decommissioning and Site Remedial Actions Data Base, a comprehensive, centralized source of information on the scientific, technological, regulatory, and socioeconomic aspects of decommissioning radioactively contaminated facilities and associated site remedial actions. The database contains 7000 records. A 10-volume bibliography (ORNL/EIS-154, 1980-1989) is available. RAPIC also maintains the Remedial

Action Contacts Data Base, which contains the names, addresses, telephone numbers, technical areas of interest, and program involvement of 1100 individuals involved in contaminated site remediation, and publishes an annual directory from this database. RAPIC staff members provide technical assistance to DOE Remedial Action Program staff and contractors on request.

Toxicology Information Response Center • The Toxicology Information Response Center (TIRC) provides information on individual chemicals, chemical classes, and a wide variety of toxicology-related topics for scientists, administrators, and the public. TIRC synthesizes comprehensive literature packages to meet specific requests. Formats include custom searches of computerized databases, manual literature searches, annotated and/or keyworded bibliographies, or written summaries of the literature. TIRC is sponsored by the National Library of Medicine.

Information Management Activities • Desktop publishing techniques have been developed for several outreach applications. A PC-based expert system, called NERC (for “NEPA Environmental Review and Compliance”), is under development for the ORNL Office of Environmental Compliance and Documentation. NERC is used in preparing documentation of compliance with NEPA requirements and other applicable federal, state, DOE, and ORNL standards for environment, safety, and health. Additional expert systems include Air Permit Regulations and Determination of RCRA/CERCLA Compliance.

5.1.7 • Integrated R&D: Building Centers of Excellence

ORNL carries out a number of activities that integrate its capabilities across disciplinary and programmatic boundaries. The Laboratory is also pursuing several initiatives to create new centers of excellence that will enhance its ability to serve an increasingly diverse set of customers.

These activities, both existing and planned, share common themes. All of them are rooted in and support DOE’s business lines. They are aimed at improving the Laboratory’s capacity to develop new knowledge, communicate and collaborate with customers, increase interlaboratory teaming, and transfer knowledge to customers. While some activities can be “located” within a specific Laboratory core competency, most cut across several competencies. In addition, these activities take advantage of the range of capabilities available across DOE’s Oak Ridge facilities. Many involve teaming with other laboratories, and others offer the potential for interlaboratory collaboration.

These activities embody a few simple but critically important concepts:

- The availability of resources—people, equipment, and facilities—is a key to the creation of new knowledge. Integrating the efforts of the people who constitute our principal resource enhances our ability to generate knowledge and transfer it to customers.
- Integration of and collaboration among synergistic resources, capabilities, and programs within Oak Ridge improves our collective ability to create new knowledge.
- Collaboration across the national laboratory system improves the system’s collective ability to create new knowledge.
- New knowledge is most useful when it is readily available to the people who will use it—our customers. Methods of knowledge transfer include cooperative R&D, user arrangements, licenses, publications, presentations, and personnel exchanges.

One of the best methods for creating and transferring knowledge in the national laboratory system is a collaborative arrangement wherein laboratory staff members work side by

side with visitors. User facilities provide a proven means of integrating effort and transferring knowledge. The activities described here draw on the success of the national user facility concept and use it as a cornerstone for laboratory centers of excellence. Such centers promote greater integration of basic research, applied programs, and technology development in DOE's programs within Oak Ridge and greater integration of activities across the national laboratory system.

Although there are some similarities, centers of excellence do not have the same function as programs staffed by intralaboratory or interlaboratory teams. Centers are custodians of the technology and as such must have an underpinning of basic science to maintain the competency on the cutting edge of technology. Programs and projects, which may be cross-cutting within and between laboratories, will take advantage of the capabilities embodied in these centers of excellence to accomplish their programmatic objectives.

In summary, the collective long-range goals of these center initiatives are to

- improve the rate of new knowledge creation,
- provide better laboratory access and quality of service for our customers,
- promote intralaboratory and interlaboratory teaming,
- avoid unintended duplication, and
- transfer knowledge to our customers by selective use and/or extension of the user facility concept.

Concentrations of talented staff and specialized facilities that function as centers of excellence, fulfilling some or all of these goals, have been in existence for years at ORNL. Their activities generally fall within one or more DOE programmatic mission areas. Table 5.5 lists existing ORNL facilities that to a large extent meet these goals. This table includes all of the DOE designated user facilities and other key research facilities. An evaluation of the role and operation of the key research facilities may suggest that some of these should also become designated user facilities.

New and potential opportunities for integrated R&D are listed in Table 5.6. This table includes the major Laboratory initiatives described in Sect. 4, which represent potential centers of excellence.

The major Laboratory initiatives will require additional funding, as discussed in Sect. 4. Developing centers of excellence based on the activities described in Sects. 5.1.7.1–5.1.7.3 will require some effort, but large amounts of additional funding are not judged to be necessary at this time. Most of the expected benefit can be obtained through new ways of working together.

5.1.7.1 • Integration of ORNL Capabilities

Center for Biotechnology

Biotechnology is an integrating science that emphasizes the development and application of biological approaches, or the use of engineering and computational capabilities, to meet national needs in health and environmental protection, biomedical applications, environmental remediation, pollution abatement, and energy production. ORNL is uniquely positioned to assume national leadership in this emerging field owing to its diversity of interactive disciplinary foundations (e.g., biology, biochemistry, molecular biology, computational sciences, chemistry, ecology, bioengineering, and biophysics) and its core competency in biological and environmental science and technology.

Table 5.5
ORNL core competencies and existing facilities

Core Competencies	User Facilities	Other Key Facilities
Energy Production and End-Use Technologies	Bioprocessing R&D Center Buildings Technology Center Computational Center for Industrial Innovation High Flux Isotope Reactor High Temperature Materials Laboratory Oak Ridge Centers for Manufacturing Technology	Center for Engineering Systems Advanced Research Oak Ridge Transportation Technology Center Radiation Shielding Information Center Robotics and Process Systems
Biological and Environmental Sciences and Technology	Bioprocessing R&D Center High Flux Isotope Reactor National Environmental Research Park Oak Ridge Centers for Manufacturing Technology	Center for Computational Sciences Carbon Dioxide Information Analysis Center Center for Biotechnology Center for Global Environmental Studies Center for Environmental Technology Center for Risk Management Ecological and Physical Sciences Study Center Global Change Research Facility Mouse Genetics Facility NASA Distributed Active Archive Center Walker Branch Watershed Center for Computational Sciences
Advanced Materials Synthesis, Characterization, and Processing	High Flux Isotope Reactor High Temperature Materials Laboratory Oak Ridge Centers for Manufacturing Technology Shared Research Equipment Surface Modification and Characterization Research Center	
Neutron-Based Science and Technology	EN Tandem Van de Graaff Accelerator High Flux Isotope Reactor High Temperature Materials Laboratory Holifield Radioactive Ion Beam Facility Oak Ridge Electron Linear Accelerator	Isotope Enrichment Facility Radiochemical Engineering Development Center Radiation Shielding Information Center
Computational Science and Advanced Computing	Computational Center for Industrial Innovation	Center for Computational Sciences Carbon Dioxide Information Analysis Center NASA Distributed Active Archive Center

Table 5.6
ORNL core competencies and planned activities

Core Competencies	Major Laboratory Initiatives	New Activities
Energy Production and End-Use Technologies	Advanced Materials Characterization Laboratory	Alliance for the Advancement of Robotics Technology Energy and Environmentally Sustainable Manufacturing Center Intelligent Measurement Systems Laboratory MPLUS: Metals Processing Laboratory User Center Oak Ridge Center for Isotope Technologies Oak Ridge Center for Surface Engineering and Coating Technology
Biological and Environmental Sciences and Technology	Center for Biological Sciences	Alliance for the Advancement of Robotics Technology Center for Separations and Chemical Processing Energy and Environmentally Sustainable Manufacturing Center Intelligent Measurement Systems Laboratory Oak Ridge Center for Isotope Technologies
Advanced Materials Synthesis, Characterization, and Processing	Advanced Materials Characterization Laboratory Spallation Neutron Source	Alliance for the Advancement of Robotics Technology Center for Separations and Chemical Processing Energy and Environmentally Sustainable Manufacturing Center MPLUS: Metals Processing Laboratory User Center Virtual Prototyping Center
Neutron-Based Science and Technology	Spallation Neutron Source	Oak Ridge Center for Isotope Technologies Oak Ridge Center for Surface Engineering and Coating Technology Virtual Prototyping Center
Computational Science and Advanced Computing		Alliance for the Advancement of Robotics Technology Virtual Prototyping Center

Among the DOE national laboratories, ORNL has the single largest biotechnology effort. ORNL is also the only national laboratory with major efforts in all three areas of biotechnology research: biomedical, bioprocessing, and environmental. Its capabilities and activities are the broadest of the national laboratories.

The ORNL Center for Biotechnology provides a coordinated focus for ORNL's biotechnology effort, integrating activities across 14 ORNL divisions and forming partnerships

with other institutions, both private and public, throughout the world. DOE sponsors include the Office of Energy Research, the Office of Defense Programs, the Office of Energy Efficiency and Renewable Energy, the Office of Environmental Management, and the Office of Fossil Energy. Other federal agencies sponsoring biotechnology R&D at ORNL include the Department of Defense (all branches, including the National Guard), the Environmental Protection Agency, the National Institutes of Health, and the National Science Foundation. Cooperative R&D agreements extend ORNL expertise in biotechnology to 14 private-sector partners. Research activities extend from the Arctic Ocean to the Antarctic and include the Human Genome Program, the development of systems for producing fuels and chemicals from renewable feedstocks, and the bioremediation of contaminated sites.

Biomedical research is directed at providing an improved understanding of the human genome and better, less expensive medical technology. In genome research, ORNL's mouse genome studies provide models for understanding the human genome in terms of genome structure/function relationships and the basis for hereditary human diseases, such as cleft palate, polycystic kidney disease, and sickle cell anemia. Cryopreservation of sperm and embryos of mice allows valuable mutants to be preserved at low cost. A computer system makes it possible to submit raw DNA sequences to ORNL by electronic mail; the positions of introns and exons are predicted by GRAIL, ORNL's Gene Recognition and Analysis Internet Link program, and the results are returned by e-mail in only a few minutes with a comparison of assembled exon sequences to sequences in the international databases. ORNL also publishes the *Human Genome News* for DOE and the National Institutes of Health. A strong structural biology program focuses on genome analysis using X-ray and neutron diffraction, three types of mass spectrometry, several forms of scanning probe microscopy, and electron microscopy with holographic analysis. Protein engineering of human growth factors is determining the essential structural features for activity. In the Laboratory's nuclear medicine program, radiopharmaceuticals are designed and synthesized to deliver radioactive isotopes to targeted disease sites in the human to make tumor inactivation and diagnosis as specific as possible. In the biosensors area, the development of an award-winning endoscope allows the use of laser light to identify cancerous regions of the human esophagus with near 100% reliability, and efforts are under way to extend this technique to other organs. The Oak Ridge Center for Healthcare Industry Development, described in Sect. 5.1.7.2, focuses on healthcare R&D through outreach to medical and industrial partners; it is integrated into the Center for Biotechnology.

Bioprocessing uses living organisms or their viable fractions to produce new products; it is the critical link between fundamental science and innovative industrial application. Industrial applications of bioprocessing have had an impact in fossil energy, chemical processing, fermentation, environmental control technology, agriculture, and biomedical advances. In support of ORNL's expanding role in bioprocessing, the Laboratory has established the Bioprocessing Research and Development Center (BRDC). A major emphasis is on bioprocessing systems that can economically produce fuels and chemicals from renewable feedstocks, including the use of appropriate waste materials. Other important BRDC activities are the development of techniques for less energy-intensive bioprocessing of petroleum and coal and systems for the degradation or removal of process pollutants. In addition, solar-energy-driven bioprocesses are being studied for production of fuels and chemicals via routes such as carbon dioxide use and recycling.

Research in environmental biotechnology combines the principles and methods of molecular biology with those of microbial and physiological ecology to address significant

environmental issues. The development of biomarkers—detectable biological responses of organisms inhabiting contaminated environments—is being used to assess changes in water quality associated with remedial actions. Because biomarkers provide an integrated measure of bioavailable contaminants and can indicate exposure to rapidly metabolized compounds, they provide information that is not available from chemical analyses of media or body burdens. Biomarkers have been used to aid Greenpeace and the Canadian government in evaluating the decline of the beluga whale population in the St. Lawrence River. In addition, a method to quantify DNA strand breaks in sunfish was developed as a biomarker of genotoxicity.

Techniques developed in molecular biology are also applied to bioremediation. These techniques have been used to enhance microbial degradation of organic contaminants and to isolate from deep subsurface environments unique groups of bacteria that may be useful in remediating sites contaminated by metals and radionuclides. In addition, DNA probes and lux-based bacterial biosensors, which emit light when exposed to contaminants, have been used to monitor biodegradation and the transport of bacteria through the subsurface. Activities have included monitoring in situ bioremediation through field demonstrations at the Savannah River Site in South Carolina and the Hanford Site in Washington. Recent collaborative research with industry includes a project with General Motors to evaluate bioremediation of contaminated groundwater at a site in Michigan and a project with REMTECH to develop a technology for the efficient biodegradation of glycol-based wastes, such as antifreeze and deicing compounds.

An approach to interorganization collaboration and to the development of a virtual center for biotechnology is outlined in Sect. 5.1.7.3.

Center for Global Environmental Studies

The exploration of global environmental issues is of critical importance in determining directions for the future. These issues are complex, interwoven, and global in scale; they include greenhouse gases, climate change, ozone breakdown, deforestation and desertification, resource depletion, the spread of pollution, and the development of science and technology to support sustainable development. The ORNL Center for Global Environmental Studies (CGES) provides an interdisciplinary base for exploring these issues through a diverse program that is tied to the U.S. Global Climate Research Program (USGCRP). The CGES focuses the Laboratory's unique capabilities in working toward three main goals:

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

Our approach includes a large-scale, long-term view; a commitment to collaboration among institutions and among disciplines; and a continual emphasis on realistic policy. The unifying framework for these efforts is global systems analysis: the development of increasingly sophisticated models reflecting the dynamic interactions of subsystems (e.g., global vegetation, human cultures and behaviors) and earth systems (e.g., atmospheric chemistry, ocean composition and circulation) and the links between air, land, and sea. The long-term goal is to develop models that include the effects of demographics, land-use patterns, economics, ecological relationships, and other factors influencing the environment.

Four areas of concentration complement this central focus:

- Measurement science and instrumentation for atmospheric, terrestrial, and aquatic research. ORNL capabilities include laser-based instrumentation; mass spectrometry and isotopic analysis; remote sensing and fiber optics; and automation, miniaturization, and portability. Applications include laser-based devices to measure trace gases, temperature, and pressure; low-cost, air-dropped packages for reading atmospheric or ocean conditions; and instruments for studying cloud formation and atmospheric properties in support of the Atmospheric Radiation Measurement (ARM) Program.
- Data systems for handling the very large amounts of data collected in the course of global environmental research, presenting the data in a user-friendly form, and ensuring the long-term usability of information.
- Large-scale environmental studies. The CGES is developing tools and techniques for understanding how to conduct research on a global scale with a longer perspective than that of traditional ecological research.
- Policy, energy, and human systems analysis. The effects of human activity and policy must be incorporated into global environmental studies. Anthropologists, climatologists, ecologists, economists, geographers, planners, political scientists, and sociologists are needed to examine the decision processes involved in global management of risks and resources. We are developing a practical approach to the problems of decision making involving many players and complex technical issues. The policy issue work of the CGES is supported through and coordinated by DOE's Office of Policy, Planning and Program Analysis (see Sect. 5.1.5.1).

Current research areas, which support DOE programmatic thrusts, include the following.

- Development of integrated land-use models. Studies of tropical deforestation in Brazil, sub-Saharan Africa, and Southeast Asia are contributing to the development of models that integrate the socioeconomic and biophysical aspects of land use.
- Refined modeling of the global carbon cycle. New models that reflect various feedbacks within the carbon cycle are contributing to the development of fully integrated carbon cycle models.
- Information analysis centers. Databases on worldwide climate (e.g., those developed by the ARM Program and the Carbon Dioxide Information Analysis Center) will be useful in determining whether global warming has occurred. Development of other areas (e.g., biomass data and human systems data) is proposed, as is development of visualization systems for data-intensive studies. We are also collaborating in an initiative to establish a Center for Human Dimensions and Global Change Data.
- International development, sustainable development, and global environment. Both climate change and climate-change policies will have significant impacts on developing countries. We are identifying vulnerable regions, determining the effects of existing aid programs on global environmental change and threats to viable futures, analyzing the impacts of change on current development plans, and finding opportunities to enhance development while pursuing environmental goals. Energy efficiency, institution building, and technology transfer for developing countries are high priorities for this activity.
- Ultraviolet B (UV-B) research. Much ozone depletion is due to various energy technologies, and other adverse effects of pollutants derived from fossil fuel may be amplified by ultraviolet light. A comprehensive effects research program on the technical issues associated with UV-B radiation should resolve many of the uncertainties dealing with

measurement sciences and instrumentation needs and is bringing a focus to the issues surrounding UV-B measurements and the effects of potential UV-B increases on biological systems.

- Integrated assessments. We are developing an interdisciplinary analysis that will allow for technological and demographic changes and indicate how climate change would affect decisions. Our long-term aim is to devise computer-based decision support systems for federal, state, and local decision makers.
- Development of improved data storage and access techniques. Our strengths in information analysis and management, combined with ORNL's expertise in scientific computing, provide a solid basis for developing better data storage systems and techniques.
- Predictive models for water resources. We are using large-scale assessment techniques and tools developed for assessment of global effects on other resources to develop an initiative in water resources directed toward the needs of developing countries. We will develop predictive models that will help decision makers understand freshwater ecology, hydrology, and water resource management in the context of global change.

The CGES is uniquely positioned to serve the needs of federal agencies and international efforts and to make a significant contribution to our understanding of the biosphere. Expected future contributions include improved understanding of the terrestrial component of the global carbon cycle, improved understanding of the effects of elevated CO₂ concentrations on plants, improvements in the performance and predictability of global climate models, effective models for integrated assessments, and improved quality and diversity of global environmental databases.

Center for Risk Management

ORNL's Center for Risk Management is an interdisciplinary R&D organization that addresses risks to human health and the environment that are associated with hazardous waste and energy production and consumption. Areas of interest include environmental restoration and other health and environmental problems—including radionuclides and toxic chemicals, acid deposition and climate changes, and policy and management mechanisms to reduce the adverse effects of these problems. Center staff draw on ORNL's diverse capabilities in health sciences, biology, environmental sciences, social sciences, and engineering to address these issues. Activities include environmental fate/transport modeling, human and environmental toxicology, epidemiology, applied ecology, environmental monitoring, database development, and risk/benefit and policy analyses.

Isotope Production Capabilities

Radioisotopes are vital to the economy and to U.S. international competitiveness: Economic benefits are over \$250 billion annually, including millions of jobs.

ORNL, which played a pioneering role in the development, production, and use of radioisotopes and stable isotopes, continues to work toward ensuring a reliable supply of essential isotope products, giving preference to supporting medical and research applications, and to fully meeting the needs of isotope users and stakeholders. This work supports the DOE National Isotope Strategy developed in 1994 by the Isotopes Production and Distribution Program and its supporting legislation, as well as other critical national needs. A vital ORNL isotopes capability is a critical component of future U.S. R&D and production activities in support of beneficial uses of isotopes.

The technical capability for beneficial uses of isotopes at ORNL consists of (1) R&D on isotope materials and potential applications; (2) development of isotope production processes and products; (3) specialty production of custom isotopes and isotope product materials for research in medicine, nutrition, biology, geology, physics, chemistry, and environmental sciences; (4) production of isotope products for crucial national needs; and (5) technology transfer of isotope production processes and products to commercial industries. The isotopes capability is synergistic with ORNL's strengths in neutron sciences, materials research, and separations science.

ORNL facilities, such as the calutrons of the Isotope Enrichment Facility (IEF), the High Flux Isotope Reactor (HFIR), and the Radiochemical Engineering Development Center (REDC), have some unique capabilities for isotope production. Other hot cell and laboratory facilities, including the Radioisotope Development Laboratory in Building 3047, are needed for recovery and purification of radioisotopes or for product fabrication. Various laboratory facilities and specialized equipment are essential for preparation of chemical and physical forms of the isotope products for specialized uses. Special-form targets are often fabricated using metallurgical, ceramic, and high-vacuum processing techniques for subsequent production of radioisotopes in accelerators and reactors.

Programmatic activities include research in support of new applications for nuclear medicine, basic research on the transuranium elements, ^{192}Ir production, stable isotope enrichment, and transuranium element production. Transplutonium element isotopes are produced in the HFIR and the REDC through the National Heavy Element Program, as described in Sect. 5.1.1.1. The REDC is the production and distribution center for transplutonium element isotopes (e.g., ^{252}Cf) in the United States and the western world.

Work is done in collaboration with other national laboratories and with various universities and research institutions in the United States and abroad. The capabilities of ORNL facilities and personnel are often used to develop, demonstrate, and transfer technology to industry and to other government programs. New isotope products and methods are developed and transferred to industry (e.g., through the cooperative R&D agreement process) when they are commercially profitable. Various new products are evaluated in collaborative programs with over 20 medical cooperative programs at clinics, universities, and other research institutions in the United States, Europe, Australia, and Asia.

Californium-252 neutron sources are supplied to more than 30 universities for teaching and research as part of the University Loan Program. Enriched stable isotopes are supplied to many universities from the Research Materials Collection, an inventory of over 200 different isotopes that is maintained for research support purposes. In addition, research collaborations with universities are frequently carried out by many of the isotope technology programs. A major collaboration will probably be required if the National Biomedical Tracer Facility is built at a university medical school; teams from the University of Alabama at Birmingham, North Texas State University, Purdue University, and the University of California at Los Angeles are currently evaluating the scientific and technical feasibility of building such a facility in the nongovernment sector.

The isotope technology programs at ORNL have a combined funding level of about \$25 million per year. Revenues from sales of ORNL-produced isotopes and technical services are estimated to total approximately \$11 million in FY 1995. All revenues are returned to the national Isotope Production and Distribution Program, and all funds are appropriated from the DOE sponsors.

Political changes and the U.S. budget deficit threaten the development of vital new replacement facilities. Maintaining and upgrading the existing ORNL infrastructure (HFIR, hot cell and laboratory facilities, and the IEF) is critical to ensuring the capability for isotope production until replacement facilities are available. The Oak Ridge Center for Isotope Technologies, a national activity for pursuing technology related to stable and radioactive isotopes, is proposed in Sect. 5.1.7.3.

Separations and Chemical Processing Capabilities

Oak Ridge expertise in separations and chemical processing was initially developed in response to the challenge of purifying crude uranium and separating isotopes. Work has continued in these areas throughout the Laboratory's history. Present programs range from the most fundamental to demonstration projects.

Separations science draws on professional expertise in solvent extraction, inorganic membranes, adsorption, ion exchange, field-enhanced separations, and dilute solution chemistry. The chemical processing capabilities of ORNL include analysis of thermophysical properties, computational chemistry, fluid mechanics, pilot-scale operations, process modeling, and life-cycle analysis. Other capabilities include equipment for testing most separations and chemical processes, extensive analytical expertise, and advanced capabilities in process control and monitoring. ORNL divisions involved include the Chemical Technology, Chemical and Analytical Sciences, Engineering Technology, Environmental Sciences, Instrumentation and Controls, and Robotics and Process Systems divisions.

The ORNL program for separations and chemical processing supports DOE programs in the Offices of Basic Energy Sciences; Nuclear Energy, Science and Technology; Environmental Management; Energy Efficiency and Renewable Energy; and Fossil Energy. Its participants, about 400 persons, hold national offices in related professional societies, serve on national committees that advise governmental agencies in these areas (principally for DOE), operate a major conference in chemical separations, and serve as editors and on the editorial boards of important journals in separations.

The following initiative proposes the development of a center for extending these capabilities to the industrial sector.

Initiative

Center for Separations and Chemical Processing

This initiative will extend ORNL's capabilities in separations science to applications of benefit to industry by establishing a Center for Separations and Chemical Processing (CSCP) at ORNL. This center will provide an integrated program and a user center with capabilities to support the U.S. chemical industry in the fields of separations and chemical processing.

Separations and chemical processing problems represent a large portion of the

technical challenges facing process industries worldwide. At the production end, requirements for purity are being placed on manufacturers of chemicals, pharmaceuticals, food, and materials are increasingly stringent. At the waste control end, the recovery of chemicals is environmentally and economically necessary. Other considerations include the need for accurate design and pilot plant data, which are essential to workable designs. The availability of good

data also minimizes engineered over-compensation and ensures more efficient use of resources and energy. Thus, the process industries face many problems and challenges that are concerns at ORNL.

The separations and chemical processing expertise available at ORNL represents a useful asset for private and public institutions that are addressing these problems and challenges. Industry has exhibited strong support, with joint research projects and cooperative R&D agreements in the emerging technologies of field-enhanced separations, thermophysical measurements, computational chemistry, computational chemical engineering, and life cycle analysis.

A survey of potential industrial users shows strong interest and support for a national laboratory center with separations and chemical processing capabilities. This interest results in part from the streamlining and re-engineering of industrial R&D in the United States, which has eliminated a number of internal process engineering groups, and from the disappearance of chemical engineering data groups in the academic community as the professors managing the research retire. The survey of industries shows that firms are beginning to plan for obtaining the needed services.

The proposed CSCP will combine ORNL capabilities in separations science, chemical processing, and supporting areas. It will have two major functions.

First, the CSCP will coordinate programmatic projects related to the separations and chemical processing problems of industry and government. These include projects such as the Chemical Plant of the Future, the

Refinery of the Future, and the Pulp and Paper initiative of the Office of Energy Efficiency and Renewable Energy; environmental programs on solving petroleum waste problems for the Office of Fossil Energy; and projects on thermodynamics and fluid mechanics for the Office of Basic Energy Sciences.

Second, the program will assist in establishing a user center for the measurement of chemical process engineering data. This Center for Chemical Processing Development will establish facilities to assist users in measuring thermophysical properties, making measurements on unit operations, carrying out pilot scale studies, and instrumenting operations under harsh conditions. Expertise and facilities will also be available for computational chemistry, process modeling, and life cycle analysis. These services will be available not only to the traditional large manufacturers but also, for the first time, to small businesses. The existence of pilot plants with unit operations would make it possible to use the facilities as a training resource for universities and industrial operations.

The CSCP will bring together activities that represent the Chemical Technology, Chemical and Analytical Sciences, Engineering Technology, Environmental Sciences, Instrumentation and Controls, Metals and Ceramics, and Robotics and Process Systems divisions of ORNL. The location of the CSCP in Oak Ridge provides some unique advantages, and participation from other organizations across the Oak Ridge Complex will be sought as part of the development of the CSCP.

5.1.7.2 • Integration of Oak Ridge Capabilities

The DOE facilities in the Oak Ridge area—ORNL, the Oak Ridge K-25 Site, and the Oak Ridge Y-12 Plant—represent a unique resource. The expertise in many areas of science and technology, manufacturing, and environmental management, combined with world-class facilities for applying these skills, adds up to a major asset for DOE and the nation.

Advanced Instrumentation and Measurement Science

Capabilities in advanced instrumentation and measurement sciences, which are widely dispersed across the Oak Ridge Complex, support nearly every scientific discipline and all of DOE's business lines. In a very real sense, all research missions at the Oak Ridge complex rely to some extent on the ability to develop advanced instrumentation and perform specialized measurements. The combination of scientific and engineering disciplines, unique facilities and equipment, and expertise at the Oak Ridge complex is unequalled elsewhere.

Work is under way to establish the Oak Ridge complex as a recognized leader in the innovation and application of advanced instrumentation and measurement systems for the benefit of DOE missions and U.S. industry. Input is being collected for a report that will serve as a "road map" for the development and coordination of the advanced instrumentation and measurement sciences capabilities by

- identifying the participants,
- defining the capabilities by technology area,
- defining a structure for using these capabilities effectively, and
- enumerating the benefits of a coherent organization for harnessing these diverse and varied resources.

The report will provide a readily available guide to the advanced instrumentation and measurement sciences capabilities of the Oak Ridge complex. It can be used in marketing these capabilities both internally and externally.

To bring these capabilities to bear on a recognized industrial need, an initiative is proposed to develop an Intelligent Measurement Systems Laboratory.

Initiative

Intelligent Measurement Systems Laboratory

The instrument and measurement industry represents a large, diverse area of the economy. In 1990, according to U.S. Department of Commerce statistics, more than 10,000 U.S. companies, representing 949,000 employees, shipped almost \$124 billion worth of instruments and related products. Most of these companies are small and have limited or no R&D capabilities.

Almost all major segments of the economy depend on measurements. Better measurement technology would allow the health care industry to decrease diagnostic costs and improve surgical support, the automotive industry to improve fuel efficiency and reduce pollution and the agribusiness industry to carry out precision farming.

A critical requirement for enhancing U.S. manufacturing and process industry competitiveness is developing or improving affordable in-process measurement technology. Japanese businesses have repeatedly demonstrated enhancements in quality and reductions in the cost of manufacturing goods through the intensive application of in-process measurement science technologies. (In a 1987 study, DOE concluded that over \$10 billion in energy costs could be saved in U.S. industry through improved sensor technology.)

The instrument and measurement industry is beginning to replace electro-mechanical sensing elements with silicon-based sensors, which transmit digital information instead of analog data. At present, 99% of the sensors in the field produce

analog output, but this should change quickly. Sensors that send digital output are easier to connect to computer data acquisition and data processing systems. These systems can incorporate computer algorithms and "if-then" rules, perform self-checking and self-calibrating, and autonomously make decisions on the basis of several measured parameters. These features may be thought of as "intelligence." Advances in the technology will improve these capabilities, resulting in more intelligent systems.

ORNL proposes to establish an Intelligent Measurement Systems Laboratory (IMSL) to assist industry in the assessment and use of intelligent measurement systems to provide energy efficiency, environmental compliance, and optimum control. As a user facility, the IMSL will provide design, simulation, prototyping, testing, and system integration facilities and technical resources requested by industry, universities, DOE, and other federal agencies. An industrial advisory board will keep the IMSL focused on the R&D needed for cost-effective higher intelligence in measurement systems. These more intelligent systems will enhance the global competitiveness of U.S. industries, provide new manufacturing jobs for American workers,

and further American education in measurement science.

Like the High Temperature Materials Laboratory, the IMSL will provide facilities and staff to industry and universities at no charge for nonproprietary R&D. Universities will provide graduate students, postdoctoral researchers, and collaborating professors. Industry will provide proposed projects and, in some cases, assigned personnel. Proprietary work that is aligned with the base R&D program will be performed at the expense of the industrial participant.

A measure of the value of the IMSL will be the amount of industry support that it attracts and maintains. We estimate that approximately 50 users per year will have agreements in place with IMSL within 5 years. Budget projections are shown in Table 5.7.

ORNL's Instrumentation and Controls Division provides a strong nucleus for a measurement science center. The Laboratory's research divisions will combine to provide a formidable interdisciplinary team that can address almost any sensor and measurement science problem or task. Strong synergy will exist between the IMSL and the Oak Ridge Centers for Manufacturing Technology.

Table 5.7
Budget projections by fiscal year for the Intelligent Measurement Systems Laboratory
(\$ in millions)

	1996	1997	1998	1999	2000	2001
DOE funding	0.2	0.6	1.5	3.0	5.0	10.0
Funding from other federal agencies	0.0	0.2	0.5	1.0	3.0	3.0
Total federal funding	0.2	0.8	2.0	4.0	8.0	13.0
Industry funding	0.2	1.0	2.0	2.5	5.0	6.0
Total funds	0.4	1.8	4.0	6.5	13.0	19.0
Distribution of funds						
Operating expense	0.4	1.8	3.4	5.0	7.0	10.0
Capital equipment	0.0	0.0	0.6	1.5	4.0	4.0
Construction	0.0	0.0	0.0	0.0	2.0	5.0

Center for Environmental Technology

The Center for Environmental Technology (CET) integrates environmental technology activities for the Oak Ridge complex, provides a focus on market-driven technology programs, and accelerates the commercialization of environmental technology innovation. ORNL, the Energy Systems Environmental Management Organization based at the Oak Ridge K-25 Site, and the Oak Ridge Y-12 Plant are partners in CET. The center is a part of the Lockheed Martin Energy Systems Environmental Management and Enrichment Facilities business unit. It is composed of six organizational elements, including the Office of Environmental Technology Development, a part of the ORNL Life Sciences and Environmental Technologies directorate, which provides research, development, and technology demonstration support.

CET uses a progressive approach to environmental management: leveraging DOE funds to achieve cost-effective environmental solutions. The total volume of revenues under CET management currently exceeds \$200 million. Since 1993, CET's return on investment has been better than 10:1.

CET links technology users and suppliers from the private sector, DOE, and other government agencies to deploy cost-effective, innovative, safe, and commercially viable technologies that will decrease the cost of environmental restoration and waste management. CET accelerates development, demonstration, and commercialization of improved technologies by providing a framework of services, facilities, and demonstration sites that expedites regulatory contracting and related operations.

Users have access to the specialized resources of the Oak Ridge complex, which include scientists, engineers, technicians, and regulatory experts along with world-class laboratories and unique user facilities for full-scale demonstrations. CET places emphasis on establishing cooperative arrangements with federal and state regulators to gain regulatory support and contracting procedures to expedite on-site demonstrations and technology transfer to and from the private sector. The long-term goal of CET is to lead the U.S. environmental industry to regain global competitiveness and increase U.S. employment.

Work will continue during the planning period to forge strong links among CET, the Oak Ridge Centers for Manufacturing Technology, and ORNL to provide a full range of capabilities in support of industrially driven environmental technology. Special emphasis is placed on establishing cooperative arrangements with industry, universities, and other federally funded R&D centers. The goal is to make the Oak Ridge complex a regional and national showcase for assisting industry with pollution prevention and control, environmental remediation, and waste management technologies, while providing much-needed solutions to problems important to DOE. Work will continue to integrate the full spectrum of Oak Ridge environmental technologies in a collaborative fashion and, where appropriate, to produce integrated strategies and operating plans. Attention is given to broadening the use of the user facility concept.

Activities are funded by DOE, other federal agencies, and the private sector. The Office of Defense Programs and the Office of Environmental Management fund much of the environmental technology work currently being performed at DOE's Oak Ridge facilities.

Oak Ridge Center for Healthcare Industry Development

The goal of the Oak Ridge Center for Healthcare Industry Development (ORCHID), established in 1994, is to provide an integrated resource to assist the healthcare industry in

lowering costs while maintaining quality. The goal will be attained through facilitated collaborations among the Oak Ridge complex, healthcare providers, academia, and industries. ORCHID is integrated into the ORNL Center for Biotechnology (see Sect. 5.1.7.1).

The unique resources in Oak Ridge include a wide range of capabilities that are of interest to the healthcare industry. ORCHID provides a mechanism for combining ORNL's expertise in biomedical research, high-performance computing, instrumentation, robotics, and sensors; the manufacturing, system integration, and prototype development capabilities of the Oak Ridge Y-12 Plant; the software development and telecommunications talents in the Energy Systems Data Systems Research and Development organization, and the resources of other Energy Systems central organizations. The Oak Ridge record of successful collaborations with private industry has attracted a number of private industry participants who are interested in biomedical projects.

Oak Ridge Centers for Manufacturing Technology

Manufacturing is a major source of high-paying and highly skilled jobs that plays a central role in the national economy. The Oak Ridge Centers for Manufacturing Technology (ORCMT), a joint initiative of ORNL and the Oak Ridge Y-12 Plant, is a national industrial resource for applied research, development, deployment, prototyping, and education. The combination of ORNL's excellence in scientific R&D and Y-12's premier manufacturing capability is unmatched anywhere in the world. The ORCMT was established to draw on the materials development, characterization, and processing expertise and the manufacturing and fabrication capabilities of Oak Ridge to improve American industrial competitiveness.

The 16 centers that make up the ORCMT are organized in 4 core technology areas. ORNL contributions to the ORCMT include three especially significant areas: modeling, mechanics, and design; materials processing and applications development; and intelligent measurement systems.

Strategic alliances with the National Institute of Standards and Technology of the Department of Commerce, southeastern state economic development organizations, educational institutions, industrial societies, and industry consortia allow the ORCMT to complement existing activities. In FY 1995, the ORCMT stimulated over \$172 million of private-sector impact in 46 states, with a strong emphasis on the southeastern United States. This represents a return on investment of more than 600% for the use of federal funds. Over a three-year period, the private-sector impact has been \$335 million. The following initiative for applying the resources of the ORCMT to industry needs for resource efficiency and pollution prevention is proposed.

Initiative

Oak Ridge Energy and Environmentally Sustainable Manufacturing Center

Manufacturing industries use one-third of the energy consumed in the United States; 70% of this energy is used for heating and power production. Improving the

energy efficiency of these industries and promoting environmentally conscious manufacturing would lower costs and improve economic productivity in this sector.

A manufacturing technology center addressing these concerns could become a major natural resource, leading to technological innovations in product and process quality, improvements in performance, and competitive costs. The Oak Ridge Energy and Environmentally Sustainable Manufacturing Center, a collaborative effort with the Oak Ridge Centers for Manufacturing Technology (ORCMT), is proposed as a means of applying ORNL's scientific and technical capabilities to industrial and government manufacturing needs for energy-efficient, environmentally sustainable manufacturing technologies. The center's activities would

- emphasize developments that sharply reduce energy and environmental

impacts while maximizing the use of sustainable materials;

- build integrated R&D alliances with the public and private sectors, including pilot-scale demonstrations;
- use private-public partnerships, including cooperative R&D agreements, to develop, demonstrate, and transfer product and process technologies; and
- maximize opportunities for customers to use the ORCMT and ORNL's unique facilities.

The proposed center would support a broad effort to establish and market ORNL as an innovative, cost-effective, responsive, and reliable partner in technology development.

Modeling and Simulation Capabilities

There is a strong and growing national movement to increase the use of modeling and simulation in the development of processes and systems. Reliance on the expensive and inefficient method of several iterations of designing, building, and testing hardware is being reduced. Organizations responsible for implementing major systems are realizing the advantage of optimizing in a virtual sense before committing resources to a final product.

Across the Oak Ridge complex, many projects with a variety of sponsors are applying modeling and simulation, either in the course of R&D activities or for actual prototype and process evaluation and verification prior to building hardware. There are also centers of expertise within the complex where prototypical hardware is being built, integrated, and tested to verify and validate computer models. Collectively, these elements represent a strong capability (about \$25 million in R&D funding for the current year) in support of DOE's businesses.

These work elements, and the growing pool of technical experts in this area, provide the impetus for development of a center of excellence for virtual prototyping.

Initiative

Virtual Prototyping Center

A Virtual Prototyping Center is proposed as a means of integrating and applying Oak Ridge complex capabilities in modeling and simulation for the development of processes and systems.

Virtual prototyping (VP) is the comprehensive application of modeling and

simulation to each step in the development of a product. It provides a totally integrated, iterative approach that involves concept development, performance evaluation, operational testing, detailed design, and manufacturing processes in an interactive computer environment. VP is an enabling

technology that is expected to become increasingly useful as resources are collected and computing resources become less expensive. Many companies have already started this process, and the results have been promising. However, a complete VP plan could be implemented to tie together all of the development steps in one comprehensive system. This VP system could be a product for small businesses, a process for large businesses, or a user facility for all types of businesses.

The Virtual Prototyping Center would draw on the resources of at least five ORNL divisions (Robotics and Process Systems, Computing and Mathematical Sciences, Computational Physics and Engineering, Engineering Technology, and Metals and Ceramics) in three research directorates; on the Y-12 Plant's Development Division; and on the Central Engineering Services and Data Systems Research and Development organizations of Lockheed Martin Energy Systems. It would also span at least four major program areas: environmental management, transportation, ammunition logistics, and space and defense technology. This initiative would use the capabilities at existing centers (e.g., the Oak Ridge Centers for Manufacturing Technology, the Concurrent Engineering Center, the High Temperature Materials Laboratory, and

the Center for Computational Sciences). Functional integration of these resources with a common vision and goals provides an expanded opportunity for synergy.

This initiative has several objectives. Of utmost importance is the integration and optimization of all VP elements currently in use at Oak Ridge. The Virtual Prototyping Center is envisioned as a comprehensive user facility, providing businesses with access to the resources and expertise located here—a capability that most businesses could not otherwise afford. The primary R&D focus would include

- modeling and simulation,
- virtual reality,
- computer applications,
- engineering and computational analysis,
- optimization (discrete and system-wide),
- supercomputing (use of massively parallel processors for virtual immersion applications),
- manufacturing technology,
- rapid prototyping, model verification, and validation, and
- materials (used in model properties as input to VP performance analyses).

This initiative also presents an opportunity to further enhance the capabilities available to industry through collaboration between the Oak Ridge complex and other DOE laboratories and facilities.

Transportation R&D

The Oak Ridge Transportation Technology Center (ORTRAN), described in Sect. 5.1.2.1, is responsible for leading the development and expansion of transportation-related research activities for DOE's three Oak Ridge sites—ORNL, the Y-12 Plant, and the K-25 site. ORTRAN was created to promote and support new research activities focused on major transportation R&D issues related to energy, environment, and security for the nation and the world. Its role is to forge partnerships within the Oak Ridge complex and with other public and private agencies and commercial industry to achieve prominence in seven areas of development:

- transportation policy and planning,
- advanced vehicle and fuel technologies,
- Intelligent Vehicle Highway Systems (IVHS),
- advanced defense transportation and deployment systems,

- hazardous materials transportation and handling,
- transportation manufacturing and construction technologies, and
- industry and university partnership development.

5.1.7.3 • Integration of National Laboratory System Capabilities

ORNL is committed to working with other DOE laboratories in applying the capabilities of the national laboratory system to national needs. As an example, ORNL has taken the lead in facilitating the creation of virtual technology centers involving DOE's multiprogram laboratories. Representatives from these laboratories, plus one team member who represents the single-program laboratories, have defined the documentation and approach for setting up centers that are a form of the "virtual laboratory." Such centers have many advantages. Strong capabilities can be created by teaming where activities are synergistic; costs can be reduced through integrated program development; customers will be better served by planned allocation of resources; and the integrated team approach can make the system of laboratories the best in the nation for specific technologies.

The first center launched through this approach is the Alliance for the Advancement of Robotics Technology. Other centers, expected to become operational within the next eighteen months, are aimed at combining national laboratory capabilities in biotechnology, isotope technologies, metals processing, and surface engineering and coating technology.

Alliance for the Advancement of Robotics Technology

ORNL performs research, development, demonstration, and application of remote systems, robotics, teleoperation, and related aspects of intelligent machines. The robotics programs are interdisciplinary in nature and use the expertise of scientists and engineers from several research and support divisions of ORNL. Over 100 scientific and technical staff members are engaged in robotics R&D at ORNL. Program activities across the full spectrum of related technologies are under way for DOE, the Department of Defense, and other sponsors.

Across the DOE laboratory and production plant complex, over 350 scientific and technical staff members are dedicated to robotics research, development, demonstration, and application. This "distributed" capability represents a unique and highly important national resource. Eight DOE national laboratories and one production plant have agreed to form a "virtual center of excellence" in robotics and remote systems technology for the DOE complex. The DOE Alliance for the Advancement of Robotics Technology (AART) will use the collective resources of its participants to develop and apply advanced robotics technology to reduce cost, improve productivity, enhance safety, and improve the effectiveness of DOE, industry, and other federal agencies. The concept, patterned on the model of the Technology Centers being sponsored by the DOE Laboratory Directors, is now rapidly evolving. The purpose of the AART is to better organize the overall resources of the national laboratory system to meet DOE and national needs and to provide better access to the technology and capabilities of the participants by industry, academia, and other federal agencies.

Interlaboratory Collaborations in Biotechnology

DOE is the principal source of funding for the three major areas of biotechnology: biomedicine, bioprocessing, and environmental research. The DOE national laboratories have

an annual budget of over \$340 million for biotechnology. Funding provided to the national laboratories from other federal agencies and the private sector approaches that from DOE, showing that the laboratories are an important national resource.

ORNL is the largest of DOE's facilities engaged in biotechnology, and it is carrying out major efforts in all three of the major areas. The ORNL Center for Biotechnology, described in Sect. 5.1.7.1, provides a mechanism for coordinating the Laboratory's resources in biotechnology with those of the other national laboratories. ORNL staff anticipate working with the other national laboratories, as part of the Biotechnology Interlaboratory Council, both to continue to develop interorganization collaboration and to work toward the development of a virtual center among the laboratories in 1996. The establishment of the council and the overall capabilities of the laboratories support this development.

Oak Ridge Center for Isotope Technologies

The Oak Ridge Center for Isotope Technologies is a network of organizations and facilities necessary for (1) performing R&D for new applications of isotopes or methods for producing them and transferring the developed technology, (2) specialty production of some isotopes, (3) routine production of some isotopes to meet crucial national needs, and (4) integrating the efforts of the distributed participants in meeting these goals.

The network of organizations is extensive, crossing disciplinary, organizational, and geographical boundaries.

- A number of ORNL divisions (Chemical Technology, Chemical and Analytical Sciences, Health Sciences Research, Metals and Ceramics, and Research Reactors) are engaged in a range of activities, from research on new applications to specialty production of isotopes.
- Other national laboratories perform R&D related to isotopes or are involved in various stages of the production process for some isotopes (e.g., irradiating targets, processing isotopes).
- The radiopharmaceutical and medical community produces isotope products, conducts research on the use of isotopes, and employs isotopes in both diagnostic and therapeutic applications.
- The industrial sector can be divided into two categories:
 - producers, who irradiate targets, separate isotopes, incorporate isotopes into appropriate chemical compounds and forms, package isotopes, and sell isotopes, and
 - users, who employ isotopes in applications such as nondestructive analysis, process control, and sterilization of medical equipment.
- The federal government uses isotopes for national security (e.g., neutron radiography of aircraft) and scientific purposes (e.g., radioisotope power sources for satellites).
- Universities conduct research into the uses of isotopes and also produce some isotopes.
- Other nations have a significant interest in both the production and use of isotopes. Many isotopes (e.g., enriched stable isotopes) are produced in only a few places, while demand is ubiquitous, so international considerations are important.

Distributed throughout this network of organizations are many facilities for producing, studying, and using isotopes. The major types of facilities include stable isotope enrichment [e.g., mass separators (calutrons), thermal diffusion], target irradiation (e.g., reactors such as the High Flux Isotope Reactor, accelerators), radioisotope processing facilities (e.g., hot cells, the Radiochemical Engineering Development Center), and waste management facilities.

The essence of the Oak Ridge Center for Isotope Technologies is to manage the particular activities related to the facilities and programs at ORNL while simultaneously taking a leadership role in networking with other organizations. The expected results are increased benefits from the use of isotopes with minimum cost impacts and supply interruptions while emphasizing participation of the private sector.

MPLUS: Metals Processing Laboratory User Center

ORNL proposes to establish a Metals Processing Laboratory User Center (MPLUS) to enhance the energy efficiency, environmental friendliness, and competitiveness of the U.S. metals industry.

This industry is essential to maintaining the nation's technological strength in a global economy.

- Metals products form components in virtually all manufactured goods; thus, a technologically superior and competitive metals industry can propel the U.S. manufacturing industry into the next century.
- Metals producers are operating in a market that is steadily becoming more international.
- Producers in the metals industry must balance the need for continued technology investment with the risks of uncertainty in the technology.

Key tools in strengthening and enhancing the metals industry are the development and integration of improved materials and processes, accurate sensors, powerful and user-friendly process design and control strategies, and material databases for process and product design, resulting in accelerated manufacturing cycles and products of higher quality and consistency. The national laboratories and other facilities of DOE possess broad capabilities for providing these tools.

Through an integrated development approach, advanced technologies and facilities can be applied for the benefit of both large and small businesses. MPLUS will provide a single site with a dedicated staff and unique facilities for performing applied metals R&D; monitoring materials performance in applications and environments of interest; addressing environmental, safety, and health questions associated with processing; resolving end-use issues for alloys and processing technologies; and providing technical support for selection of metals, processing methods, and general fabrication considerations for many applications.

MPLUS will make use of user centers and alliances with industries and universities, and it will provide a basis for collaboration with major materials, manufacturing, and computational centers at ORNL and the Oak Ridge Y-12 Plant. The primary capabilities in MPLUS will include

- metals processing,
- metals joining,
- metals characterization and properties, and
- metals process modeling.

Since the development of end-use products often requires incorporation not only of metals processing skills, but also of more generic materials issues, the extensive experience in the development and use of ceramics and composites represented by the capabilities available in Oak Ridge provides a major advantage of MPLUS.

Formation of MPLUS to assist industry and academia in solving metals processing issues will have wide-ranging advantages and will provide a unique national resource. In addition, by helping to satisfy customer requirements for price, quality, and delivery,

MPLUS will meet the goals of the Office of Energy Efficiency and Renewable Energy and the Office of Industrial Technologies (OIT). MPLUS will be an important part of OIT's efforts to meet the materials and processing needs of the "Industry of the Future," with a focus on the following industries:

- chemical,
- forest products,
- foundry,
- glass,
- petrochemical, and
- primary metals (steel, aluminum, copper, magnesium).

Goals for MPLUS include enhancing company productivity and profitability by accelerating manufacturing cycles, improving product quality and consistency, and reducing waste. Increases in productivity and profitability should be achieved in conjunction with a reduced risk to the environment and should produce a safer, cleaner, and healthier working environment for employees. Ultimately, for the development effort to be effective, the technology must be affordable, and the program must include strategies for the commercialization of the developed technologies and for the dissemination and implementation of the technologies in all sectors of the metals industry. It must also provide for training, particularly in small companies, where the challenge of implementation of advanced technologies is likely to be the greatest.

Oak Ridge Center for Surface Engineering and Coating Technology

ORNL possesses a broad and diverse range of capabilities for surface modification and coating technologies, spanning multiple divisions and extending from advanced materials deposition technology to surface alteration via chemical, mechanical, and physical means. Skills and facilities, though technically diverse, share common qualities in their application to advanced materials development and in their extensive use in collaborations with the manufacturing sector. The creation of the Oak Ridge Center for Surface Engineering and Coating Technology, as a center of excellence representing the broad capabilities of the DOE national laboratory system, is proposed.

The deposition of materials in coatings of varying thickness and the surface modification of substrates and coatings support a variety of activities in ORNL divisions and in the Oak Ridge Centers for Manufacturing Technology. These activities include plasma spraying, thin-film vapor-phase and plating deposition at both research and production-scale levels, and laser ablation (Engineering Technology Division); ion implantation and thin-film rechargeable batteries (Solid State Division); chemical vapor deposition, diamond coatings and surface characterization and analysis (Metals and Ceramics Division); and plasma source ion implantation (Fusion Energy Division).

Advanced chemical and physical vapor deposition facilities at ORNL support activities ranging from thin-film batteries to fixation of unusual materials (including organics) on a variety of substrates. Technology for laser ablation of oxides is being developed for highly controllable deposition of complex advanced material. Surface cleaning techniques based on pellet injection technology, developed for fueling fusion experiments, are being applied to conventional industrial uses such as paint stripping. Ion implantation for surface toughening is being expanded with plasma sources that conform the ion species to the irregular shape of the target, improving distribution uniformity over less sophisticated

line-of-sight methods. A full range of interdisciplinary surface characterization capabilities, including morphology and composition, chemical and mechanical properties, and machinability, is available.

ORNL capabilities in surface modification/engineering of materials are broad and may be best summarized as a coupling of experience in solving challenging problems and world-class materials expertise. The Laboratory's scientific and technological capabilities are applied to industrial and government needs to provide energy-efficient and environmentally sound alternatives, and the results of applied R&D are transferred to production use.

Surface modification and coating technology play a crucial role in supporting DOE missions in energy production and use. Surface modification and coatings can directly contribute to energy efficiency and drastically reduce energy consumption throughout product life cycle. Surface modification technologies also serve to enhance the use of sustainable raw materials that are environmentally benign or mitigate impacts. For example, beryllium plasma spraying is a leading candidate in containment/shielding fabrication for the International Thermonuclear Experimental Reactor and the National Ignition Facility. Intermetallics, special high-temperature alloys, composites, and other materials are all expected to be used in applications for energy production, efficiency, and use.

5.2 • Work for Others

Work undertaken for federal agencies other than DOE, nonfederal agencies, private organizations, and the Nuclear Regulatory Commission accounts for about 15% of the Laboratory's total budget. The level of funding for work for others (WFO) is expected to remain relatively stable over the next several years. However, the distribution of work for non-DOE sponsors is changing, moving from an emphasis on Department of Defense support to other agencies as the defense budget declines. An increasing amount of the WFO work is expected to involve support from private industry in terms of technology transfer or Laboratory-industry partnerships.

Much of the existing WFO effort at ORNL consists of relatively small (<\$500,000) projects. This emphasis on small projects tends to dilute the efforts of staff and to consume a disproportionate amount of support staff. Increasing the number of large (>\$5 million) projects would allow for more efficient use of staff and resources.

The goal over the next several years is to transform the current program into a more balanced split between large and small projects. Achieving this goal may require broader collaboration with other parts of the Oak Ridge complex as well as other national laboratories. ORNL is engaged in a collaborative effort with the Energy Systems Office of Technology Transfer, the Hazardous Waste Remedial Action Project, the Data Systems Research and Development organization, the National Security Program, and several other R&D programs to explore new ways of effectively responding to new opportunities that might involve WFO.

ORNL staff are also participating in the Added Factor/Waiver Policy Task Team chartered by DOE's Work for Others Working Group. This team is focusing its efforts on reexamining the added factor waiver criteria and procedures and on developing proposals for changing current policy.

5.2.1 • Federal Organizations

5.2.1.1 • Nuclear Regulatory Commission

Current ORNL efforts for the Nuclear Regulatory Commission (NRC) reflect the Commission's priorities: response to public attitudes requiring a high degree of confidence in the safety of nuclear power, the maturing of the current generation of U.S. nuclear reactors, and certification of the next generation of reactors. Completion of the more than 100 nuclear plants ordered in the 1960s and 1970s, coupled with the upcoming expirations of operating licenses for many of these plants, has shifted the emphasis of NRC research toward structural and component safety issues, structural aging research, analysis of reactor operational data, advanced instrumentation and diagnostics, accident sequence analysis, and license extension requirements. The NRC is also working to certify four advanced light-water reactor (LWR) designs and the Canadian CANDU-3 design. ORNL funding from the NRC supports work in each of these areas, but it is expected to decline slightly over the next several years as NRC's reduced budget encourages an increased use of internal staff.

ORNL performs work primarily for three offices within NRC: the Office of Nuclear Regulatory Research (RES), the Office for Analysis and Evaluation of Operational Data (AEOD), and the Office of Nuclear Material Safety and Safeguards (NMSS). RES, the major sponsor of ORNL activities, conducts comprehensive research programs that lead to regulatory guidelines and standards issued by the NRC. AEOD collects, analyzes, and evaluates operational safety data to identify areas requiring NRC or industry action. NMSS is charged with overseeing public health and safety licensing activities in the nonreactor nuclear arena.

Nuclear Regulatory Research

During the planning period, the NRC will continue to give priority to investigating long-term behavior of reactor pressure vessels, severe accident issues, instrumentation and controls technology, and issues relating to extension of the operating licenses of existing power plants beyond their original 40-year period. ORNL is developing a structural aging handbook and a materials property database for aging concrete structures in U.S. nuclear power plants.

Other research at ORNL contributes to the NRC's Severe Accident Research Plan (documented in NUREG-1365, Rev. 1). These efforts include work on boiling-water reactor (BWR) core-melt progression and in-vessel strategies for addressing potential severe accident conditions. ORNL staff collaborate with Sandia National Laboratories and Idaho National Engineering Laboratory to improve the MELCOR and RELAP/SCDAP codes for LWRs and extend their applicability to scenarios for severe accidents in BWRs. Other severe-accident code development work supports NRC cooperative research agreements with Germany (CORA-BWR experiments) and with seven other nations to develop and validate computer codes for modeling fission product behavior and core-melt progression under severe accident conditions (Cooperative Severe Accident Research Partners). Support is provided for other NRC-developed codes such as CONTAIN.

The NRC continues to place high priority on research to ensure the integrity of reactor pressure vessels in commercial nuclear power plants. ORNL is the lead laboratory for this work, which includes the Heavy-Section Steel Technology (HSST) program, the Heavy-Section Steel Irradiation (HSSI) program, and the Surveillance Data Base, Analysis, and

Standardization (SAS) program. The NRC integrates the results of these programs into its reactor regulation process and into its agreements with foreign states (e.g., the activities of the Joint Coordinating Committee for Civilian Nuclear Reactor Safety with Russia and other states of the former Soviet Union).

The HSST program investigates issues concerned with validating safety margins for prevention of reactor vessel fracture under all feasible loading conditions. Large-scale fracture experiments and advanced analysis methods are being used to investigate the impact of shallow flaws and localized thermally induced constraints in association with emergency core-cooling scenarios. Results of experiments are factored into national consensus standards and NRC procedures. The support will continue to include supplemental pressure vessel safety research for advanced LWR designs that the NRC is working to certify.

The HSSI program is extending databases and the basic understanding of physical mechanisms associated with radiation-induced damage (e.g., embrittlement) in pressure vessel steels. Base metal, welds, and cladding are included. Radiation experiments are performed to verify the applicability of damage models to prototypically thick sections of each material. The program includes studies of the degree to which degraded steel properties recover when thick sections of irradiated steel are annealed at relatively high temperatures for long periods of time. R&D activities relating to irradiation embrittlement of reactor pressure vessel steels continue to be considered of the highest priority to nuclear safety by the NRC and the international community. Assistance is given to the NRC's consideration of the state of embrittlement of specific operating plants.

The SAS program maintains for the NRC the national operational surveillance database on embrittlement of pressure vessels in commercial reactors. These data are used to develop improved correlations for predicting the state of embrittlement, and the results have direct applications in license renewal and life-extension assessments, which will continue to be major NRC concerns. Attention is given to determining the compatibility of data from other nations with the U.S. database and to possible combination of these data. ORNL leads the NRC effort to develop and examine an international database on embrittlement; this effort is coordinated with the International Atomic Energy Agency.

A Generic Environmental Impact Statement appropriate for license renewal rule-making was developed with ORNL assistance and listed in the Federal Register for public comment. ORNL is working with the NRC to assess the comments and assist in the resolution process.

The NRC sponsors safety research to support certification of advanced LWRs. ORNL provides support in the areas of thermal hydraulics code validation, assessment of severe accident evaluation, instrumentation and control methodologies, and pressure vessel and materials studies. As the NRC extends its considerations of the advanced reactor designs, ORNL's support efforts are expected to increase.

The journal *Nuclear Safety*, funded by the NRC and coordinated by ORNL staff, provides safety information to the nuclear industry. Publication is expected to continue.

Analysis and Evaluation of Operational Data

ORNL projects sponsored by AEOD, which serves as a focal point for the continuing independent assessment of operational performance of nuclear power plants, emphasize the collection, review, analysis, and evaluation of plant safety performance data. Support to AEOD is expected to remain roughly constant.

The Accident Sequence Precursor (ASP) Project identifies nuclear power plant events that are considered precursors to accidents with the potential for severe core damage and uses risk assessment methodologies to determine the quantitative significance of events. ORNL is assisting in the resolution of operational performance issues, benchmarking the operating records of individual power plants for diagnostic assessments, trending events, providing technical assistance, and responding to inquiries from NRC staff on operational and safety-related issues.

ORNL operates and maintains the Sequence Coding and Search System (SCSS), the NRC's official database on reportable operational events at commercial power plants. SCSS is a highly structured system that supports detailed searches of operational occurrences, ASP analyses, the NRC's performance indicator programs, and identification of common-cause failures. ORNL also maintains data systems on reactor events in other nations, international incident reports, and power plant performance indicator data and appropriate statistical models developed for the interpretation of these data. ORNL provides support to AEOD through the NRC's performance indicator program by evaluating events to determine their cause, monitoring changes in plant performance, and compiling corrective action data needed to prevent plants from developing serious problems.

Nuclear Material Safety and Safeguards

NMSS currently sponsors a number of projects at ORNL. Most of these are expected to continue, and new projects are expected to take the place of those that come to an end. NMSS funding at ORNL is expected to remain at about the current level or to increase gradually over the planning period.

For the Division of Fuel Cycle Safety and Safeguards, current projects include technical support for nuclear criticality safety analyses; assessment of technical criteria for the termination of safeguards on nuclear material contained in irradiated waste; safety and environmental review assistance; technical assistance in the preparation of the *Standard Format and Content Guide* and the *Standard Review Plan* for license applications for fuel cycle facilities; nuclear awareness seminars for multiple-agency threat analysts; technical assistance for Russian, Ukrainian, and Kazakhstani material protection, control, and accounting; technical assistance for licensing of uranium enrichment facilities; and technical assistance for assessing the effectiveness of the low enriched uranium reform rule and its implementation.

For the Division of Industrial and Medical Nuclear Safety, current projects include cask analysis and review, review of license files for records related to research involving human subjects, general license inventory system management and analysis, safety and environmental review assistance, and review of terminated license files.

For the Division of Waste Management, current projects include technical support to the Ukrainian State Committee for Nuclear and Radiation Safety on specific waste issues and technical support for design, construction, operation, and performance reviews for low-level waste.

Other Offices

ORNL provides technical assistance to the NRC Office of State Programs in the review of Agreement State regulations and programs, to the Office of Nuclear Reactor Regulation in evaluations of BWR stability phenomena and in design reviews of advanced

LWRs, and to the Office of Information Resources Management in the areas of information management and model development.

5.2.1.2 • U.S. Department of Defense

ORNL carries out R&D for the major Department of Defense (DOD) services—the Army, Navy, Marines, and Air Force—and for joint agencies such as the Defense Nuclear Agency, the Advanced Research Projects Agency (ARPA), and the U.S. Transportation Command (USTRANSCOM). Several projects are managed by Energy Systems organizations, and all projects are considered part of an Energy Systems central organization.

Army

ORNL research for the Army includes programs in materials science and technology, optics, instrumentation and control systems, robotics and intelligent systems, human-machine interface technology, transportation systems, operations research, and environmental and work force analysis. ORNL is also studying the feasibility of using high-volume hazardous waste streams as supplementary feedstocks in industrial boilers, developing surface-enhanced Raman scattering for chemical detection, developing eye protection devices to prevent laser damage, and developing impact statements for the demilitarization of chemical agents.

Primary responsibility for managing technology base research within the Army is assigned to the Army Research Laboratory (ARL). ORNL is developing several cooperative programs in fundamental research with ARL, including work in advanced materials, microelectronics, robotics, and advanced computing.

Work will continue on a major research initiative concerning the aging of materials, electronics, and other components in Army weapon systems. A major materials study will continue for the Armament, Chemical and Munitions Command, and related work will continue in advanced composites, ceramics, carbon/carbon bonding, intermetallics, and related technologies. Research in material processing and analysis techniques, including mathematical and computational modeling of crack propagation, will continue. These projects are designed to develop advanced armor and shielding as well as lighter-weight components for increased mobility of weapon systems and vehicles. Advanced shielding materials and processing concepts will be evaluated for ARPA, the Army Corps of Engineers, the Ballistics Research Laboratory, the Tank Automotive Command (TACOM), and other agencies. Work also continues on advanced materials for reentry vehicles and space applications.

Initiatives continue in advanced instrumentation and robotics and intelligent systems technology, including advanced robotics concepts for ARL, Fort Belvoir R&D Center, and related agencies. Programs to defend against high-energy agile laser technology for the battlefield are also planned. These include teaming with TACOM to develop viewfinders for tanks and armored vehicles to reduce the potential for laser damage to the eyes of soldiers on the battlefield. Stand-off detection of agents using advanced laser techniques will be studied. Communication and information technology for battlefield integration will be evaluated.

Researchers in the ORNL Robotics and Process Systems Division (RPSD) continue the development of automated systems for battlefield rearm technology. Current projects include the Advanced Integrated Robotics Rearm System, the Modular Artillery Ammunition Delivery System, and the Smart Crane Ammunition Transfer System. In a collaborative effort involving RPSD and the ORNL Chemical Technology Division, work is under way to develop processes or additives to stabilize the liquid propellant used for artillery shells.

R&D for the Army in operations research and transportation systems, energy conservation, energy security, fuels research, and advanced engineering command continues. Included among these projects are the development of telecommunications system 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 and the Army Reserve and Recruiting Command is expected to grow moderately over the planning period. ORNL is providing analytical techniques for force structure and mobilization planning and related civilian missions.

ORNL proposes to support the Army National Guard's modernization program by assisting the National Guard Bureau in establishing and operating a National Guard Technology Center. The center will provide a wide range of technology and technical assistance to the National Guard Bureau Headquarters and state organizations to evaluate and take advantage of the latest technology to implement the Guard's modernization program.

The Army's Chemical Research, Development, and Engineering Center supports efforts to refine techniques for detecting biological and chemical materials in the air. Various combinations of lasers, optical fibers, and advanced spectroscopic techniques are used to support the Army's efforts to develop instruments that can be used on future battlefields.

ORNL staff are participating in environmental compliance audits for the Rocky Mountain Arsenal and assisting with the analysis of environmental matters for the Army Corps of Engineers and the Waterways Experiments Station. A series of Applicable or Relevant and Appropriate Requirements investigations has been conducted at contaminated Army sites, and efforts continue to provide a computational framework for inferring radiation doses from bioassay measurements. Technical assistance is provided to the U.S. Army Center for Health Promotion and Protection (formerly the Army Environmental Hygiene Agency) in preparing Material Safety Data Sheets for incorporation into DOD's Hazardous Material Information System.

Work also continues for the Picatinny Arsenal to develop, evaluate, and test new designs for compulsators and power systems for electromagnetic and advanced gun systems.

Navy and Marine Corps

ORNL conducts research for the Navy and Marine Corps in engineering systems, instrumentation, data systems, reliability and maintenance, materials R&D, fuel supply and use, diesel testing, human factors engineering, energy conservation, and waste disposal. This research has diverse applications and has contributed significantly to many Navy and Marine Corps programs located at a variety of laboratories and institutions.

ORNL's Navy Mobility Fuels Forecasting System is being used to evaluate the fuel production effects of the U.S. Clean Air Act. In addition, ORNL plays an important role in instrumentation and engineering R&D for the Carderock Division, Naval Surface Warfare Center (CDNSWC), the Navy's primary research, development, test, and evaluation center for naval vehicles. Two primary areas of interest to the CDNSWC are ship and submarine silencing and methods to design and test high-strength hulls and components. ORNL assists the CDNSWC 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. ORNL also continues to evaluate new technologies for the Navy's advanced submarine R&D program.

ORNL provides a variety of design, engineering, and development support for the Coastal Systems Station in the areas of submarine countermeasures, amphibious warfare, naval special warfare, and mines and mine countermeasures. ORNL is also providing electronics development and human factors engineering support for the Naval Medical Research Institute in areas related to divers and diving. ORNL research for the Naval Air Systems Command 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 with effective trainer interface design.

For other Navy facilities, R&D continues on instrumentation and equipment reliability and maintenance; methods are being explored 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 techniques to modernize naval systems. Other R&D efforts include electronic component design cost-effectiveness, life-cycle analysis, and prototype development for the Naval Sea Logistics Center, a computer-aided research project for the Naval Sea Systems Command.

ORNL has conducted several materials R&D programs for the Navy. Among them is a program to fabricate pressure hull prototypes made of polymer matrix composite for submersible vehicles.

For the Office of Naval Research, in conjunction with the DOE Environmental Measurements Laboratory, Argonne National Laboratory, and Los Alamos National Laboratory, ORNL is tracking the movement of radionuclides to characterize the extent of radioactive contamination in the Arctic basin resulting from nuclear testing and waste disposal conducted by the former Soviet Union. The Office of Naval Research is also providing funding for a Molecular Design Institute that involves a consortium of universities and private companies, as well as ORNL, in the design of better materials for a variety of applications.

ORNL also provides technical assistance to the Navy Environmental and Health Center in Norfolk, Virginia, by preparing Material Safety Data Sheets and hazardous material assessment reports to support the hazard communication standards of the Occupational Safety and Health Administration, the Superfund Amendment Reauthorization Act, and the right to know of the community.

ORNL staff provide technical support and assistance to the Navy on compliance with environmental regulations, on the potential health effects of hazardous materials used by Navy personnel, and for the Navy's Radon Assessment and Mitigation Program.

Air Force

For the Air Force, ORNL performs research on environmental systems, advanced materials, advanced fuels, data systems, waste management, and related areas.

A major economic analysis activity supports the Air Force Civil Engineering Support Agency (AFCEA) and the Air Force's major commands. ORNL performs economic analysis and provides 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 AFCEA includes evaluating Air Force base energy requirements to assess whether these requirements can be met cost-effectively by increased coal consumption.

In support of the Installation Restoration Program, ORNL staff have performed remedial investigation/feasibility study projects for chemically contaminated Air Force sites. They

also conduct Environmental Compliance Assessment and Management Program audits of bases in the Air Combat Command. Researchers are investigating the effects of polycyclic aromatic hydrocarbons on fish in lakes near Otis Air Force Base, a Superfund site, and aiding in the design and testing of new bioreactors and microbial consortia. ORNL is also involved in developing a five-volume Installation Restoration Program toxicology guide that incorporates a wide range of toxicological data, including carcinogenicity, genotoxicity, teratogenicity, and short-term and long-term exposure effects on humans.

For the Wright Laboratory, ORNL is performing research in multisensor integration algorithms for hypercube computer architectures. Hypercube computer architectures offer supercomputer capabilities in a small volume (which is ideally suited for robots and satellites). This research augments and complements DOE robotics multisensor integration research being carried out at ORNL. ORNL is also providing R&D support to the Wright-Patterson Air Force Base in weigh-in-motion systems.

A major environmental R&D activity will continue to support the Air Force Environmental Impact Analysis Process in which both programmatic and site-specific analyses of Air Force actions are addressed. ORNL conducts environmental compliance assessments for various Air Force commands.

Military Transportation

ORNL has conducted extensive R&D for the DOD transportation agencies. ORNL's Center for Transportation Analysis blends complementary work for DOE, the Department of Transportation, and the various defense transportation agencies, linking such WFO sponsors as the Federal Aviation Administration, the Federal Highway Administration, and the three components of USTRANSCOM—the Air Mobility Command (AMC), the Military Sealift Command, and the Military Traffic Management Command. The AMC Deployment Analysis System has been expanded to take on the task of planning and scheduling the operation of the air refueling fleet.

Support for the DOD transportation user community will be provided through the Oak Ridge Transportation Technology Center (ORTRAN), described in Sect. 5.1.2.1. Areas of research include decision support systems and modeling; development of a program for efficient, standardized noncombat vehicles; and planning and development of transportation technologies that support efficient deployment.

Defense Nuclear Agency

ORNL performs research for the Defense Nuclear Agency in support of the Human Response Program. The human factor in the military nuclear environment is addressed through models and databases that predict the human response in all nuclear threat situations. 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 multiphase plan that includes definition and analytic validation of the initial and protracted radiation environments, shielding calculations for tactical armored vehicles, and extensive comparison of existing and new methods to assess radiation impacts on military vehicles and human beings.

The Defense Nuclear Agency also supports research at ORNL to define more accurately the effects of nuclear radiation on the crew and components of tactical combat vehicles. In addition, it supports the Radiation Shielding Information Center (see

Sect. 5.1.6.2) to provide an information analysis center for Defense Nuclear Agency contractors involved in radiation transport R&D.

The Defense Nuclear Agency is currently undertaking a mission to develop computational tools and databases for the assessment of hazards associated with nuclear, biological, and chemical facilities throughout the world. ORNL research supporting this program includes the characterization of the hazardous source term in nuclear facilities, the potential release of source terms under various accident scenarios, the dispersion of source terms, and the deleterious effects to the near-range and far-range population. A central focus of the ORNL research is the development of HASCAL, the Hazard Assessment and Consequence Analysis computer code system, which includes the construction of a set of industry standard models for each reactor and nuclear facility type. Research also includes the generation of databases characterizing the source term production and release rates that can be coupled to air dispersion models. The ultimate goal is to assemble the models and databases into a fast-running hazard analysis tool for use by military field personnel.

Other Department of Defense Agencies

ORNL performs site characterizations and performance assessments for potentially contaminated sites and for new facilities at DOD installations (Air Force, Air National Guard, Navy, Army) with the primary objective of assessing contamination problems. ORNL works to apply innovative techniques, to identify and pursue research needs based on observations at numerous field sites, and to communicate lessons learned and research applications in the technical literature.

5.2.1.3 • National Aeronautics and Space Administration

The NASA Earth Observing System Data and Information System (EOSDIS) is a key component of the U.S. Global Change Research Program. ORNL is one of nine Distributed Active Archive Centers (DAACs) through which the scientific research community can acquire data and information from EOSDIS. The ORNL DAAC is described in detail in Sect. 5.1.6.2.

5.2.1.4 • U.S. Department of Health and Human Services

The U.S. Department of Health and Human Services supports research in carcinogenesis, protein engineering, protein crystallography, genetics, and toxicology. Funding from this source is expected to remain reasonably constant over the planning period. The majority of funding is from the National Institutes of Health (NIH); some funding is from the U.S. Food and Drug Administration (FDA).

Genetic, reproductive, and general toxicology databases (see Sect. 5.1.6.2) are being developed, analyzed, and evaluated for the FDA, the National Library of Medicine, and the National Toxicology Program, with support from the Environmental Protection Agency.

The National Cancer Institute (NCI) supports research on the expression of pre-neoplastic markers in tracheal cells. ORNL is studying cell interaction and the role of transforming growth factor-beta (TGF- β) in the control of tracheal cell proliferation. With the National Heart, Lung, and Blood Institute, NCI also sponsors work in the ORNL nuclear medicine program to develop a basic understanding of the chemistry and physiology of cerebrovascular and cardiovascular imaging agents.

The National Institute for Child Health and Human Development (NICHD) supports a program on the induction of insertional mutations by means of transgenic technology. Caused by integration of foreign DNA into the host genome, such mutations are valuable for correlating gene structure with function. NICHD also supports research on fundamental cryobiology and preservation of spermatozoa. A project on cryopreservation of human spermatozoa, complementing cryobiology research funded by DOE's Office of Health and Environmental Research.

The National Institute of General Medical Science supports studies to improve the understanding of hydrogen-bonded biological systems. ORNL scientists are investigating the hydrogen-bond structure of macromolecules with X-ray and neutron diffraction and with analysis programs running on supercomputers.

For the National Institute for Environmental Health Sciences (NIEHS), ORNL is enlarging the database on the response of germ cells to chemicals. The induction of both gene mutations and chromosome aberrations is being measured, and these genetic lesions are being studied in depth. ORNL has also developed a computerized database on transgenic mice and is mapping transgene integration sites. The Environmental Mutagen Information Center (see Sect. 5.1.6.2) also receives support from NIEHS.

Analytical tools developed for use by the Agency for Toxic Substances and Disease Registry (ATSDR) for evaluating reports of clusters of health effects near hazardous waste sites will be made available via a user-friendly program for a microcomputer. ORNL also provides guidance to 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. ORNL has also developed a geographical information system for use in evaluating health effects.

The National Institute on Aging supports frozen embryo banks for several mouse and rat strains developed for aging studies. The National Institute of Allergy and Infectious Diseases supports investigations of thymus dysfunctions in a mutant mouse that may be a model for certain autoimmune diseases. ORNL is also conducting studies of the molecular basis for polycystic kidney disease for the National Institute of Diabetes and Digestive and Kidney Diseases. For the National Institute of Dental Research, ORNL is studying the molecular genetics of cleft-palate development.

5.2.1.5 • U.S. Environmental Protection Agency

ORNL's work for the Environmental Protection Agency (EPA) addresses numerous health and environmental problems and issues. Research focuses on identifying the effects of pollutants associated with energy production processes, effluents, and disposal.

ORNL staff members are conducting ecosystem simulations to relate the effects of contaminant releases to ecological responses. Other research addresses the toxicity of leachates from solid waste and the human health effects from incineration of hazardous chemicals. ORNL also provides technical support to the National Acid Precipitation Assessment Program II and measures the response of high-elevation forest ecosystems to atmospheric deposition.

For the Environmental Monitoring and Assessment Program, ORNL staff members are developing an analysis of ecological indicators, as well as landscape characterization and integrated assessment approaches for the overall program.

Literature reviews and chemical hazard information profiles are prepared for EPA-selected topics and chemicals. ORNL will continue to provide administrative management, coordination, and information support to the EPA GENE-TOX program. Support for the Chemical Unit Record Estimate (CURE) database, including the development of a personal computer-based version of selected information from the CURE master file on over 1900 chemicals, will also continue (see Sect. 5.1.6.2).

Health risk assessment activities are addressing chemical carcinogenicity and chronic toxicity, electromagnetic fields, and diesel emissions. The EPA is also supporting research at ORNL to evaluate the use of physiologically based pharmacokinetic models in the risk assessment process.

In other work, ORNL is evaluating the ecological risk associated with land application of municipal sewage sludge. Plant and animal community changes, microbial processes, leaching of nutrients, and erosion are being examined for eastern deciduous forest southeastern loblolly pine plantation, southwestern semiarid range land, and northwestern Douglas fir forest ecosystems. The study will aid EPA in revising municipal sewage sludge use and disposal standards, as directed by the Clean Water Act.

5.2.1.6 • National Science Foundation

Research sponsored by the National Science Foundation (NSF) examines a variety of environmental concerns. The NSF supports studies of spatial gradients in nutrient cycling and their effect on stream ecosystem stability, drawing on the Walker Branch Watershed and using radioisotope tracers to research key factors in stream response. The understanding derived from this research will benefit ORNL studies of disturbed aquatic systems on the Oak Ridge reservation that are being conducted in concert with remedial action efforts.

ORNL continues to provide technical assistance to the NSF Division of Polar Programs in evaluating the environmental impacts of the U.S. Antarctic Program. ORNL is developing site- and project-specific environmental impact assessments, with emphasis on waste and fuel management, sensitive resources, and global concerns for the Antarctic.

The NSF supports research to evaluate the scientific bases for assumptions used in risk assessment. The results are intended for use by federal agencies responsible for regulating human exposure to chemical carcinogens. The NSF also supports a program to develop methods for maintaining genetic lines of *Drosophila* in a frozen state. New cryopreservation techniques being developed at ORNL have the potential to replace cumbersome and costly traditional breeding techniques.

The NSF's Industry/University Cooperative Research Program funds the University of Tennessee at Knoxville's Measurement and Control Engineering Center, a collaboration with ORNL and a variety of industrial partners. The Measurement and Control Engineering Center has capabilities related to analytical instrumentation, process controls, signal/image processing, and predictive maintenance.

5.2.1.7 • Federal Emergency Management Agency

ORNL programs for the Federal Emergency Management Agency (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, developing devices that protect against the effects of electromagnetic pulses, 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 also include

- development of a national system for infrastructure information,
- emergency preparedness for 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,
- risk communication and public awareness,
- 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.

5.2.1.8 • U.S. Agency for International Development

ORNL serves as a center of expertise on energy planning, policy development, and renewable energy applications for the U.S. Agency for International Development (AID) Office of Energy and Infrastructure in the Bureau of Research and Development. ORNL's activities include research; analysis; technical assistance; project development, implementation, and evaluation; and information dissemination. Efforts in energy planning and policy development emphasize energy efficiency improvement, environmental management, transportation systems, R&D roles, institution building, and technology cooperation. In renewable energy applications, ORNL emphasizes biomass energy systems and rural/decentralized applications. ORNL also supports programmatic activities in other AID components.

5.2.1.9 • U.S. Department of Transportation

The Department of Transportation provides funding to the Oak Ridge Transportation Technology Center (ORTRAN; see Sect. 5.1.2.1) and also supports the Center for Transportation Analysis, which covers all transportation modes. ORNL is assisting the Federal Highway Administration, the National Highway Traffic Safety Administration, the Office of Pipeline Safety, the Federal Transit Administration, the Federal Aviation Administration, and the Bureau of Transportation Statistics in research areas that include development of freight and passenger demand models; assessment of data quality and data consistency of highway statistics; development of data collection methods and advanced data management systems to improve data integrity and availability; analysis of nationwide surveys to address issues in current or future national transportation policies; development of methods to statistically link data sources to study intermodal traffic; and research on intelligent vehicle highway systems. A program begun in FY 1995 provides technical assessment of oil and gas pipeline systems throughout the United States for compliance with regulatory standards.

The Center for Transportation Analysis is engaged in a major initiative to provide technical support to the Federal Highway Administration on the Intelligent Transportation System. One aspect of this is a CRADA between ORNL and Scientific Atlanta, Inc., on the development of a portable automatic data acquisition system for crash avoidance research.

5.2.1.10 • U.S. Department of Commerce

ORNL is providing technical leadership in support of the Coastal Change Analysis Project (C-CAP). C-CAP is sponsored by the Coastal Ocean Program of the National Oceanic and Atmospheric Administration (NOAA) and administered through NOAA's National Marine Fisheries Service. ORNL's primary responsibility is to conduct R&D on land-cover monitoring in the coastal regions of the United States, in support of a national effort to monitor land cover gains and losses.

ORNL provides planning, technical coordination, and implementation of regional projects designed to employ the C-CAP protocols. Each project involves collaboration with a university, state government agency, or other regional organization. Technology transfer will be a key technical requirement in the collaborative efforts. Regional projects include Galveston Bay, the Louisiana coast, Tampa Bay, the South Carolina coast, the North Carolina coast, the Rhode Island coast, the St. Croix estuary, San Francisco Bay, the Columbia River estuary, the Alaska coast, and south Florida. ORNL processes satellite images and other data in support of these regional projects, develops improved methods and techniques for measuring spectral change, develops new methods and techniques for assessing accuracy in large spatial databases involving change over time, and is assisting in establishing an operational center for C-CAP at the Center for Coastal Ecosystem Health in Charleston, South Carolina.

5.2.1.11 • Other Federal Agencies

ORNL provides technical support to a variety of other federal agencies, including the U.S. Department of Agriculture (USDA), the U.S. Department of State, and other agencies. The Laboratory anticipates collaborative work with the USDA, including the Agricultural Research Service, the U.S. Forest Service, and USDA research laboratories.

Support provided by the State Department for work performed for the International Atomic Energy Agency and the United Nations Educational, Scientific, and Cultural Organization is expected to continue. ORNL is also assisting the U.S. country studies program in support of the Intergovernmental Panel on Climate Change, which is led by the State Department and supported by DOE, EPA, and AID. ORNL continues to assist the National Park Service in evaluating the environmental impact of extensions of the Foothills Parkway, adjacent to the Great Smoky Mountains National Park.

ORNL is assisting the Tennessee Valley Authority (TVA) in an assessment of the potential for biomass energy within the TVA power system. In addition, a major contract is in progress to conduct R&D for TVA in areas of mutual interest. These include the development of advanced diagnostics, advanced instrumentation and controls for TVA power plants, and techniques to improve the efficiency and reliability of TVA's transmission and distribution systems; assistance in improving end uses; and evaluation of the health effects of electromagnetic fields. TVA is a partner in the Joint Institute for Energy and Environment, described in Sect. 5.2.2.3.

Support is provided to the Bureau of Labor Statistics in artificial intelligence systems to provide estimates of consumer prices index and survey automation. Work is anticipated in support of the Office of National Drug Control Policy and its various support agencies.

ORNL provides support in environmental management of water resources to several other federal agencies. For example, ORNL staff serve as technical advisors to the Bureau of Indian Affairs and the U.S. Army Corps of Engineers on environmental issues such as hydro-power impacts on fish and wildlife and instream flow policies.

5.2.2 • Nonfederal Organizations

ORNL performs research for and in collaboration with many nonfederal entities, both public and private. These efforts support DOE's mission to apply the resources of the national laboratories to issues and problems of national importance, especially in the areas of energy resources, environmental quality, and economic competitiveness.

5.2.2.1 • Electric Power Research Institute

The Electric Power Research Institute (EPRI) funds research at ORNL in areas related to the generation and efficient use of environmentally acceptable electric energy. The Laboratory expects to continue research in these areas for EPRI during the planning cycle.

Understanding the processes that control the atmosphere/surface exchange of mercury is the focus of an ORNL project that employs a number of proven field techniques, integrated with laboratory studies, to quantify the deposition and emission of mercury in forests and surface waters. The work is a joint effort involving ORNL, the National Oceanographic and Atmospheric Administration, and the Swedish Environmental Research Institute.

A program on compensatory mechanisms in fish populations has the overall objective of improved predictions of fish population response to disturbance. This program complements ORNL's work for DOE's Hydroelectric Program.

EPRI continues to fund research at ORNL in areas related to the efficient use of electric energy. An efficiency research project now under way is testing full-size ice storage systems for cooling commercial buildings.

ORNL's expertise in biomass energy is being applied to analyzing the potential of biomass feedstock for electric power plants. Interaction with the ORNL Biofuels Feedstock Development Program is expected to increase.

EPRI is co-funding the development and demonstration at ORNL of intelligent control systems for nuclear power plants (see Sect. 5.1.1.2). 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 carries out technology development for EPRI in the area of high-temperature structural design methods and fracture assessment procedures for advanced reactors and other high-temperature power plant components. In these activities, ORNL serves as EPRI's R&D arm in collaborative studies between EPRI, the Central Research Institute for Electric Power Industry in Japan, and the Central Electricity Generating Board in the United Kingdom. Results of these joint studies help to meet identified needs in DOE's reactor programs.

Assessment of the role of volatile salts (e.g., ammonium chloride) in the carryover of corrosive species in steam generator circuits has been limited by a lack of data and predictive models. Data obtained at ORNL are being incorporated into broader thermodynamic models.

EPRI also funds research at ORNL in the application of chaos theory to diagnosis and control of power generation systems. Recent activities have focused on characterization of fluidized bed combustion hydrodynamics and the development of data analysis algorithms for extracting nonlinear information from fluidized bed measurements. As part of this activity, ORNL has developed a close collaboration with the Technical University of Delft in the Netherlands and with Babcock and Wilcox (B&W), a major U.S. boiler manufacturer. It is anticipated that EPRI-sponsored fluidized bed research will continue, augmented by a major new thrust in the application of chaos to analyzing and controlling boiler flame dynamics, especially in regard to emission reduction.

Associated with EPRI research is work funded by the B&W Owners Group to develop an improved control system for currently operating B&W reactors. 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 is a control algorithm that will be implemented by the B&W Owners Group on new digital control hardware.

5.2.2.2 • American Petroleum Institute

The American Petroleum Institute supports research at ORNL to evaluate the pharmacokinetics and pharmacodynamics of benzene in humans, with the aim of providing a better estimate of the risk of developing leukemia following exposure to low doses of benzene.

ORNL also provides support to the American Petroleum Institute 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.

5.2.2.3 • Joint Institute for Energy and Environment

The Joint Institute for Energy and Environment is an organizational entity established by ORNL, the Tennessee Valley Authority, and the University of Tennessee to conduct research and other collaborative activities on critical topics related to energy and the environment. Skills and facilities from theoretical research through laboratory explorations to full-scale demonstration projects are combined with policy and social science expertise to address research topics such as the science and policy implications of climate change; the role of environmental education, training, and technology transfer in global economic development; domestic and international energy and environmental policy; and energy production and conservation.

With funding from the National Science Foundation, the Joint Institute is establishing the National Center for Environmental Decision-Making Research. The center will develop new study methods, analysis tools, and processes to help government and private enterprise make use of scientific research in their environmental decision-making.

5.2.2.4 • Other Nonfederal Organizations

Private industry has joined with ORNL through CRADAs, licensing agreements, user agreements, and other mechanisms. ORNL also interacts with many other nonfederal entities, including

- Battelle Laboratories,
- SEMATECH,
- EG&G Energy Measurements, Inc.,
- the General Electric Company,
- the Florida Institute of Phosphate Research,
- the Metropolitan Edison/General Public Utility,
- the Pacific Power and Light Company,
- the Northwest Power Planning Council,
- the Soap and Detergent Association,
- the states of California, Virginia, and Alaska,
- the Canadian Atomic Energy Commission,
- the Federal Republic of Germany Umweltbundesamt,
- the Japan Atomic Energy Research Institute,
- the Korea Advanced Energy Research Institute,
- the National Institute of Radiation Protection of Sweden,
- the United Kingdom Atomic Energy Agency,
- the International Atomic Energy Agency,
- the National Geographic Society,
- the Center for Indoor Air Research,
- the Gas Research Institute, and
- Oak Ridge Associated Universities.

5.3 • LDRD Program

The principal objective of the ORNL Laboratory Directed Research and Development (LDRD) Program is to provide financial support for innovative R&D ideas that, while within the general mission of the Laboratory, have no direct programmatic funding. Such ideas can and do lead to productive new technical directions for the Laboratory, DOE, and the nation. The program, which obtains its funds from DOE through an overhead charge to all other Laboratory programs, operates under the authority of DOE Order 5000.4A, "Laboratory Directed Research and Development" (April 9, 1992). All LDRD project funding requires the approval and authorization of the Laboratory director.

The LDRD Program comprises two major activities: the Seed Money Fund and the Director's R&D Fund. The Seed Money Fund is a continuation of the original ORNL Seed Money Program initiated in 1974; the Director's R&D Fund was added in 1983. The FY 1995 budget was \$12.7 million; \$3.0 million was allocated for the Seed Money Fund, and \$9.5 million was allocated for the Director's R&D Fund. The remaining \$200,000 was placed in an LDRD capital equipment fund, and the full amount was spent on Director's R&D Fund projects. The total budget authorized for LDRD amounts to less than 2% of the total operating budget for ORNL. Table 5.8 lists funding for FY 1994–FY 1997.

Proposals for Seed Money Fund projects are accepted directly from the Laboratory's scientific and technical staff 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. (Requests for less than \$15,000 can be approved by the LDRD

Table 5.8
Laboratory Directed R&D funding by fiscal year
(\$ in millions—BA)

	1994	1995	1996 ^a	1997 ^a
Total funding	10.2	12.7	13.1	13.1

^aEstimated.

Program Manager.) Each of these nominally one-year projects is generally funded at less than \$130,000; the average project budget in FY 1994 was \$71,694.

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 R&D Strategic Planning Committee, which is composed of senior Laboratory managers and research staff members. These projects may continue for a maximum of three years, although most have durations of one to two years. The average FY 1994 budget for these projects was \$198,000; total budgets for three-year projects average about \$540,000. From 5 to 10% of the Director's R&D Fund is allocated individually by the Laboratory associate directors.

In selecting projects for FY 1996, the R&D Strategic Planning Committee chose to consider high-quality proposals in any research area, with preference given to proposals of an interdisciplinary nature that strengthen or emphasize the Laboratory's core competencies.

Providing multiple routes of access to LDRD funds maximizes the likelihood that novel ideas with scientific and technological merit will be recognized and supported. The selection process allows for the fact that new ideas are generally initiated by R&D staff, provides for peer review of proposals, and engages management in fostering projects that are oriented to the strategic directions of the Laboratory.

The LDRD Program is administratively part of the ORNL Office of Planning and Special Projects. The position of program manager rotates every two years among ORNL scientific and technical staff members. Additional descriptions of the program can be found in

- *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; and
- *Measuring Investment in R&D Excellence: A Study of Laboratory Directed Research and Development at the Nine DOE Multiprogram Laboratories*, DOE/ER-0361, U.S. DOE, December 1992.

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 three times the program's investment. The program provides the scientific and technical staff with morale-boosting incentives to be innovative. Many of the honors, awards, and new programs at the Laboratory have their origins in work supported by the LDRD Program.

The annual program plan for the LDRD Program, which is prepared and submitted to the DOE Office of Energy Research in accordance with DOE Order 5000.4A, serves to request LDRD funding for the Laboratory and to provide a general description of and justification for the LDRD program.

6 • Critical Success Factors

6.1 • Continuous Improvement

6.1.1 • Reengineering ORNL

In September 1995, the Department of Energy (DOE) elected to establish a separate contract for the management and operation of ORNL, as described in Sect. 1. With ORNL's separation from Lockheed Martin Energy Systems, Inc., and the establishment of Lockheed Martin Energy Research Corporation (LMER) came an opportunity to position the Laboratory for maximum competitive advantage.

In 1996, ORNL will undertake a reengineering effort that will focus on reducing costs and enhancing R&D. This effort, to be conducted with support and guidance from an outside management consultant, is aimed at providing

- a corporate structure for ORNL that supports and is responsive to the research and development (R&D) mission,
- a working environment that ensures maximum scientific productivity and staff member reward,
- operating policies and controls that ensure the highest quality R&D performance in compliance with all applicable requirements, and
- "Best Industry Practices" support and services to R&D programs at minimum cost.

Strategies include focusing on the Laboratory's customers, benchmarking against other national laboratories and industry, and ensuring maximum staff participation. Optimization analyses will provide the basis for make/buy decisions on support functions (e.g., security, training, procurement). Optimization decisions will be implemented by September 1996.

This reengineering effort is part of ORNL's commitment to implementation of the Secretary's Strategic Alignment Initiative. Cost reduction objectives include a reduction of Laboratory overhead by at least four percentage points and a 15% reduction in the full-time equivalent employee (FTE) cost in R&D divisions by the end of FY 1997. Objectives for enhancing R&D include removal of barriers, streamlining of processes, and a move to "necessary and sufficient" regulation.

6.1.2 • Monitoring and Measuring Quality of Performance

ORNL has used the Malcolm Baldrige National Quality Award assessment process as a strategy for continuous improvement. This process provides for regular assessment of the Laboratory's

- leadership,
- information and analysis,

- strategic planning,
- human resource development and management,
- process management,
- business results, and
- customer focus and satisfaction.

The Laboratory's first internal assessment using the criteria for the Baldrige Award, in spring 1994, revealed strengths and weaknesses in ORNL's approach to quality. A second assessment in 1995 focused on areas targeted for improvement: R&D productivity issues, major barriers for R&D effectiveness, program development and evaluation, and formal customer relations. The results of this assessment were submitted to DOE as an Energy Quality Award application. Plans are to conduct an internal assessment every other year.

The institutional planning process and the strategic planning process, both of which are conducted by senior Laboratory management, provide the framework for the establishment of challenging goals, which is a cornerstone of total quality management (TQM). The *ORNL R&D Strategic Plan*, which is summarized in Sect. 3, documents goals and strategies for achieving them. The Laboratory also monitors and measures quality of performance at several levels.

Individual Performance Plans

Goal setting is an essential element of career development and performance improvement for individual staff members and managers. ORNL uses a performance planning and review system to evaluate individual job performance. Each salaried employee develops an annual performance plan with specific goals under the guidance of his or her supervisor. Supervisors annually appraise employee performance, using progress toward achieving these goals as input for the appraisal.

The performance management cycle for the current year has some new features: it incorporates employee preparation of a self-assessment of the past year's performance, includes a set of performance factors, provides for an optional mid-year review, formalizes matrix manager input into performance reviews of matrixed employees, and continues an employee development focus while encouraging employees to be partners in their own performance management and development. The new system places greater emphasis on continuous improvement, teamwork, and customer focus and satisfaction.

Division and Programmatic Long-Range Plans

Divisions and programs use strategic planning to set performance goals; performance is monitored internally and by advisory committees. An annual statistical publication, *ORNL Facts and Trends*, provides Laboratory management with data on R&D productivity in each division.

Laboratory Performance Plans

Performance planning for ORNL has undergone major changes with the transition to the new contract arrangement. These changes reflect DOE's commitment to move from compliance-based relationships with contractors to relationships that are based on performance determined by objective measures.

The contract between DOE and LMER provides for the use of performance measurements to promote continuous improvement and provides a basis for evaluating contractor

performance. Performance measures have been developed in four areas: programmatic, institutional management, operations support, and administrative. Initial performance targets have been determined, and LMER will annually report the performance measures to DOE. Standards of performance will be reviewed annually, and processes are in place for negotiating and establishing changes in performance measures as needed.

ORNL is actively supporting the Department's move to performance-based oversight of contractors by participating in four pilot projects that address business practices; environment, safety, and health; program technical reviews; and necessary and sufficient processes. Self-assessment will be a primary tool for the Laboratory.

ORNL Facts and Trends provides information about staff, programs, outside interactions, and performance to Laboratory management. Reviews and guidance are also provided by the ORNL Advisory Board, which convenes at the Laboratory twice a year.

6.1.3 • Quality Assurance Program

A formal Quality Assurance (QA) Program applies to all activities conducted by or for ORNL. This program incorporates planning for prevention of problems, quality control to assure conformance to requirements, and continuous performance improvement. Independent audit functions verify compliance with QA requirements and evaluate the effectiveness of QA programs. Self-assessments are conducted to evaluate performance and identify areas of improvement. The Office of Quality Programs and Inspections, part of the ORNL Operations, Environment, Safety, and Health Directorate, supports ORNL managers in the implementation of programs that foster effective R&D; accomplish environmental, safety, and health (ES&H) objectives; and meet quality requirements.

6.2 • Human Resources

Human resources goals have been established in four areas: valuing diversity, exhibiting genuine concern for the quality of life and morale of our people, providing opportunities for enhancing skills, and promoting and celebrating success.

ORNL works to recruit and retain staff members with the skills and abilities needed to carry out planned programs. This effort includes encouraging professional growth, recognizing achievement, and providing an environment consistent with corporate values and work force diversity that affords equal employment for all.

6.2.1 • Valuing Diversity

ORNL has played a key role in DOE's demonstration of its commitment to diversity and vision to be a recognized leader within the federal government. At the first DOE Diversity Conference in July 1994, the Secretary of Energy recognized the contributions of ORNL Director Alvin Trivelpiece to the success of the conference.

ORNL will continue its work to build and maintain an inclusive environment. In addition to a high-level emphasis on equal employment opportunity (EEO) and affirmative action (AA), the Laboratory will work toward increasing the cultural diversity of the work force, promoting acceptance of and appreciation for cultural diversity, and accommodating the needs of a changing work force. The Office of Work Force Diversity plays an integral role in

these activities. *Diversity Works*, a newsletter published by the Office of Work Force Diversity, will serve as an important means of communicating information on programs and activities in these areas.

Equal Employment Opportunity and Affirmative Action Program

EEO/AA is an integral part of all personnel functions and activities for the Laboratory. The Office of Work Force Diversity administers the ongoing EEO and AA programs; monitors progress in hiring, promoting, and developing minorities, women, persons with disabilities, and Vietnam-era and disabled veterans; monitors hiring goals and staffing levels; and ensures management awareness of EEO/AA issues. The office also responds to a variety of concerns raised by salaried employees.

The Laboratory is committed to equal employment opportunities for its employees and for applicants who seek employment at ORNL. Support for the EEO/AA program begins at the top and is communicated down to all other levels of management and supervision to foster a shared sense of responsibility for its success. Accountability for support of EEO/AA program activities is addressed in measures of performance for management staff members.

An ongoing AA plan, administered through the Office of Work Force Diversity, ensures that all employment and promotion decisions are predicated on the principle of equal opportunity. Statistics on employment of women and minorities in FY 1989 and FY 1994 are shown in Tables A.6 and A.7 in the Appendix.

A Diversity Council, with representatives from senior Laboratory management and employees, develops strategies for ORNL to meet EEO/AA challenges. The Annual EEO/AA Awards Breakfast provides recognition to individuals and divisions that have made outstanding contributions to the EEO/AA program.

An area receiving particular emphasis at ORNL is increasing the representation of women and minorities in upper/senior management positions. Significant progress is being made in this area. Strategies are being implemented to increase the mentoring and development of internal candidates and to identify and hire, where opportunities exist, experienced external candidates for these positions.

Increasing the Diversity of the Work Force

Projections show that by the year 2000, over half of those entering the work force will be women and minorities. The number of persons with disabilities entering the work force is also expected to increase. ORNL is instituting changes in personnel policies that will be required to meet the different needs of this changing work force. Work force issues are also being identified and considered by Lockheed Martin task forces.

ORNL actively seeks to recruit and develop minority candidates for management openings. These efforts will continue during the planning period. The professional growth programs described in Sect. 6.2.3 will provide an internal source of candidates for key management positions, and external recruiting efforts will be intensified.

The Laboratory is also engaged in a variety of programs to "fill the pipeline" of scientific and technical talent with underrepresented minorities and women. Education programs sponsored by DOE (see Sect. 5.1.1.1) promote outreach to underrepresented and underserved populations. These programs include

- significant interfaces with historically black colleges and universities, including technical and staff support for the establishment of a graduate program in radiation protection at Florida A&M University and a partnership with North Carolina A&T University that has included over \$2 million in subcontracting activity over the past several years;
- participation in the National Consortium for Graduate Degrees for Minorities in Engineering and Sciences, Inc. (GEMS), which has resulted in the employment of three ORNL staff members with graduate degrees; and
- a partnership with the Southeastern Consortium for Minorities in Engineering, which included seven interns during the summer of 1995.

The Laboratory uses nontraditional recruiting sources, including consortia such as GEMS, to assist in diversifying its scientific and technical staff. Advertisements for scientific and engineering positions are placed in publications that target women and minorities.

Efforts that reach beyond the Laboratory include the Minority-Owned Business Technology Transfer Consortium, a new effort begun in 1993 to promote R&D collaborations with minority businesses. This initiative served as a model for the Diversity Conference held in Washington, D.C., in July 1994.

The ORNL Committee for Women fosters and promotes ORNL as a preferred workplace for women. The committee has sponsored a series of information bulletins that address topics such as child care, mentoring, work schedule options, and summer internships, using the Laboratory's daily Inside Line to communicate this information. Additional information on flextime, mentoring, and leadership has been made available in the Central Research Library and through the local chapter of the Association for Women in Science. The Committee for Women also sponsors "brown bag lunches" with discussions on leadership and policy. A member of the committee was the point of contact for the Fourth Annual DOE Review of Laboratory Programs for Women, and seven delegates from ORNL, including the director of the Office of Planning and Management, attended this meeting.

A special ORNL publication, *Pioneer Women*, profiles several women staff members at the Laboratory. This brochure is used for recruiting and for promotion of ORNL's educational programs. It is available electronically on ORNL's World Wide Web page.

The Laboratory will continue to emphasize recruiting and hiring qualified people with disabilities. Plans for recruiting and hiring people with disabilities are developed and implemented annually from the Office of Work Force Diversity at ORNL.

Promoting Cultural Diversity

The manager of the ORNL Office of Work Force Diversity is responsible for promoting the importance, benefits, and economic advantages of a culturally diverse work force. A variety of programs and events recognize the diversity of ORNL staff. Some of these are sponsored by the Office of Work Force Diversity, while others are sponsored by divisions or other organizations at the Laboratory. Examples include special programs for the Martin Luther King, Jr., birthday observance; Asian Pacific Heritage Week; Hispanic Heritage Month; Black History Month; Native American Month; and Women's History Month.

A formal training program in cultural diversity promotes acceptance and strengthens ORNL's commitment to an inclusive workplace. An annual workshop is held to communicate, to senior managers, the Laboratory's expectations with regard to promoting diversity and to share strategies for meeting these expectations.

A special publication highlights the diversity of ORNL staff members and describes diversity in ORNL's external activities. This brochure was distributed to Laboratory staff members and is also used as a recruiting tool. It is available electronically on ORNL's World Wide Web page.

Accommodating the Needs of a Changing Work Force

The company's part-time employment policy and the "employee convenience time" concept provide options in scheduling to employees. Progress has been made in developing "flextime" and "flexible workplace" policies to provide additional options. The flextime program provides a work scheduling system that gives employees discretion in choosing the specific hours of work each day. The flexible workplace program will allow employees with temporary disabilities to work out of their homes for a specified time and will also provide the company with a system to recruit qualified individuals with severe disabilities who may need to work at home.

As access barriers fall and technology evolves, Americans with disabilities are expected to assume a greater role in the ORNL work force. The Laboratory will continue to emphasize recruiting and hiring qualified people with disabilities, based on plans developed annually by the Office of Work Force Diversity.

The ORNL Disability Program Oversight Committee, formed in 1991, ensures compliance with policies and procedures relating to the Americans with Disabilities Act. The committee's efforts are aimed at improving access to facilities at ORNL.

6.2.2 • Quality of Life

Achieving ORNL's goal of exhibiting genuine concern for the quality of life and morale of its staff members will be accomplished in several ways. Human resources activities in valuing diversity, professional growth, and recognition programs provide support to this area. Goals for the Laboratory's business practices (see Sect. 3.3) also address this key task.

6.2.3 • Professional Growth

The diverse nature of ORNL's businesses requires a high-quality, multidisciplinary staff. The educational backgrounds of the current professional staff are shown in Table A.8 in the Appendix. During the planning period, ORNL will place additional emphasis on employee development, movement, and mentoring. Formal and informal programs are offered to enable staff members to meet new challenges.

At the direction of the Deputy Laboratory Director, ORNL has established a task team to develop a plan for enhancing employee development at the Laboratory. Team members include an associate Laboratory director, line managers, the director of the Lockheed Martin Energy Systems Human Resources Organization, and the manager of the ORNL Office of Work Force Diversity.

Upward mobility for minorities and women is receiving special attention from Laboratory management. Succession planning identifies candidates for key management positions; diversity is a consideration in this process, and the Energy Systems Human Resources Organization assists ORNL management with this process to ensure that women and minorities are considered for these positions.

The Laboratory's Educational Assistance Program is an effective tool for helping employees achieve their academic and career goals and for helping to ensure the availability, optimum utilization, and continuing welfare of skilled employees. The Laboratory also provides in-house development programs designed to meet specific needs for education and training. A degree program administered by American Technical Institute, originally proposed to serve a specialized group (reactor operations shift workers) at ORNL, now serves students from all of DOE's Oak Ridge facilities. Performance planning process now includes the optional preparation of a development plan to identify areas for growth and development.

ORNL will continue to provide specialized training programs to address issues of concern to employees, such as sexual harassment awareness training and smoking cessation clinics. ORNL's management training includes courses that present strategies for communicating across cultural barriers and for appreciating cultural diversity. This area of management training is crucial in preparing managers for the changing work force of the future.

The formal mentoring program allows participants to become better acquainted with and more visible to organizations beyond their own divisions. The interactions created by these relationships also provide employees with an opportunity to gain additional insights that are useful in developing career objectives.

The ORNL Committee for Women addresses career development issues such as education, mentoring, and workplace attitudes. The committee will study these issues and focus on those deemed critical to its goals.

6.2.4 • Recognition Programs

ORNL strives to provide a challenging environment for research and to reward excellent performance. Several financial and nonfinancial incentive and recognition programs reward outstanding contributions and significant achievements. One of these, the Special Achievement Awards Program, is a financial incentive program that recognizes employee contributions. Employees are recognized based on the achievement of special goals, milestones, and/or assignments of substantial impact on organizational programs. Another program pays inventors for technology licensed or transferred to private industry.

ORNL participates in an annual corporate awards night, which recognizes outstanding performance in publications, technical achievement, management support service, inventions, operational performance, and administrative/technical support. Special achievements and accomplishments of ORNL employees are also recognized through announcements in a variety of in-house publications (e.g., *Lab Notes*, the electronic "Inside Line"). The ORNL Honors and Awards Office nominates employees for awards external to the organization, publicizes awards received by ORNL staff members to the Laboratory community, and maintains records of award winners.

6.3 • Environment, Safety, and Health

6.3.1 • ES&H Goals and Objectives

ORNL is committed to conducting operations and R&D in a manner that protects the environment, the public, and Laboratory staff while allowing the conduct of world-class research in a competitive manner. In attaining this goal, ORNL takes an integrated approach

to environment, safety, and health (ES&H) matters. Individual employees are responsible for ensuring that their work is carried out in compliance with ES&H requirements. Self-assessment against high standards of ES&H compliance is an essential part of the ORNL culture. A broad program, coordinated through the Laboratory's Operations, Environment, Safety, and Health Directorate, supports the line organizations in addressing ES&H issues and provides internal appraisals and audits to ensure that requirements are met.

The Laboratory's ES&H goals, objectives, and strategies are documented in the *Oak Ridge National Laboratory Environment, Safety and Health Implementation Plan*, ORNL-6801 (March 1994), and presented in Table 6.1. Detailed strategies and action items for these goals and objectives are given in ORNL-6801.

6.3.2 • Current Conditions

ORNL expects a number of changes in the regulatory environment in which it currently operates as the result of DOE's efforts in performance-based oversight and directives reduction.

ORNL is participating in four pilot processes as part of DOE's performance-based oversight pilot laboratory oversight program: business practices; program technical reviews; ES&H; and a "necessary and sufficient" initiative. All of these processes, but especially the ES&H pilot process and the "necessary and sufficient" initiative, are expected to change the Laboratory's operating environment. ORNL also expects changes in its environment as a result of DOE's accelerated review of directives, in which the Laboratory has taken a leadership role. The application of consistent performance-based requirements, the clarification and coordination of oversight roles, and the shift from inflexible requirements to a system that applies "necessary and sufficient" measures should improve efficiency, lower costs, and increase productivity and focus on mission execution.

6.3.3 • ES&H Plans and Initiatives

Strategies have been developed for addressing each of the ORNL ES&H objectives. These strategies detail the actions necessary to achieve the objectives. In addition, numerous program, compliance, and response plans provide guidance in other ES&H activities that are necessary for the continued operation of the Laboratory but do not relate specifically to the stated ES&H goals and objectives.

Safety and health

Table 6.2 provides the estimated cost of safety and health for ORNL (based on input to the DOE Safety and Health Five-Year Plan). These estimates were developed through analysis of expected needs at the Laboratory. Actual funding for future years has not been determined. All activities associated with these costs have been ranked using the DOE Safety and Health Risk Priority Matrix, and the results have been submitted to DOE's Oak Ridge Operations Office for transfer to the responsible primary secretarial offices.

ORNL's facility safety documentation will be updated to accommodate the emerging nuclear safety management rules. The implementation plan strategy for the rules includes participation in DOE's Price-Anderson Amendments Act pilot program and close coordination of issues and impacts with DOE before submittal of rule implementation plans. Funding to meet implementation plan commitments is a significant issue.

Table 6.1
ORNL ES&H objectives

Health and safety objectives

1. Maintain and continue improvement in the protection of worker safety and health.
2. Involve all our people in preventing workplace accidents and illnesses and in protecting the public from off-site releases.
3. Improve radiological protection and performance of radiological controls.
4. Achieve and maintain compliance with health and safety laws, regulations, orders, and agreements.
5. Achieve excellence in all aspects of safety and health performance.
6. Increase the satisfaction of our customers and stakeholders and their confidence in Energy Systems in managing safety and health performance for DOE facilities. Clearly understand their requirements and desires and strive to meet them.
7. Achieve integrated and consistent systems and teamwork in the medical, personnel health, industrial hygiene, industrial safety, and radiation protection areas.
8. By 1998, update Safety Analysis Reports.
9. By 1997, become recognized as a premier innovator in developing and implementing effective protection of worker safety and health.

Environmental objectives

1. Achieve and maintain excellence through protection of the environment and full compliance with applicable environmental laws, regulations, DOE orders, and agreements.
 2. Over the long term, achieve a minimum-discharge operation in which raw and used materials are reduced at the source, reused, or recycled. Ensure that any remaining discharges to the air, water, or land are minimal and are not considered harmful to people or the environment.
 3. Ensure that risks to the environment and human health posed by past operations are either eliminated or reduced to prescribed levels through cost-effective cleanup or containment.
 4. Enlist, empower, and support all Energy Systems personnel in the challenge of protecting the environment, conserving natural resources, preventing pollution, and complying with applicable environmental laws, regulations, DOE orders, and agreements.
 5. Increase the satisfaction of our customers and stakeholders and their confidence in Energy Systems in managing the DOE facilities. Clearly understand their requirements and desires and strive to meet them.
 6. Continue the development of and maintain an Energy Systems-wide management system for environmental information.
 7. Continually improve the self-assessment process to identify issues, determine root causes, develop and validate corrective action plans, monitor progress, verify completion, identify trends, and document lessons learned.
 8. Help DOE to ensure adequate environmental protection programs in all of its activities.
 9. Improve systems for the dissemination of requirements by identifying needs for policies and procedures to implement applicable laws, regulations, DOE orders, and agreements.
 10. Become recognized as an innovator in research and development, testing, demonstrating, and transferring new environmental science and technologies.
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Waste minimization and pollution prevention

The ORNL Pollution Prevention Program performs the planning and reporting functions that are required by state and federal laws and DOE orders. The program also provides coordination, training, and technical assistance to waste-generating divisions. The Pollution Prevention Program addresses all categories of waste generated at ORNL: sanitary/industrial, radioactive, hazardous, and mixed.

The Pollution Prevention Program also administers a program of awareness for pollution prevention, as required by DOE Order 5400.1. The program is designed to heighten

Table 6.2
Safety and Health Plan funding by fiscal year^a
(\$ in thousands)

	1996	1997	1998	1999	2000	2001
Indirect	52,016	59,068	59,114	57,887	58,864	43,227
Operating ^b						
Energy Research	66,445	61,375	32,520	24,674	24,587	21,257
Nuclear Energy	2,444	1,261	0	0	0	0
Total operating	68,889	62,636	32,520	24,674	24,587	21,257
Capital equipment						
Energy Research	5,951	3,075	2,845	2,307	2,113	385
Total capital equipment	5,951	3,075	2,845	2,307	2,113	385
GPP ^c						
Energy Research	2,531	8,000	2,000	1,037	450	450
Total GPP	2,531	8,000	2,000	1,037	450	450
Line item						
Energy Research	5,000	1,200	4,900	22,852	20,400	17,700
Total line items	5,000	1,200	4,900	22,852	20,400	17,700
Total Safety & Health	134,387	133,979	101,379	108,758	106,214	83,018

^aDoes not include cost from Energy Systems central organizations distributed to ORNL.

^bIncludes division administration as a direct operating expense.

^cGeneral Plant Project.

employee awareness of the waste reduction initiative and to emphasize the value of each individual's contribution to reducing waste. Table 6.3 provides the funding requirements for the Pollution Prevention Program.

NEPA process

ORNL is a leader among DOE facilities in the application of the National Environmental Policy Act (NEPA) process for its planning activities. Projects are reviewed to determine the applicability of NEPA. Preliminary screening identifies whether projects may qualify for a categorical exclusion or may require more detailed environmental assessments. Project managers are kept informed of the status of their projects, and a dedicated staff prepares and tracks the necessary documentation. DOE personnel make the determination of the proper classification of projects and must approve all projects, but the efforts of the ORNL staff facilitate the actions of DOE.

Table 6.3
Waste Minimization Plan funding by fiscal year^a
(\$ in thousands-BA)

	1995	1996	1997	1998	1999	2000	2001
Waste Management	1,100	70	70	70	70	70	70
Energy Research	213	530	610	628	646	665	684
Total	1,313	610	680	698	716	735	754

^aWaste minimization funding is included in the Waste Management costs in Table 6.4.

6.3.4 • Environmental Management Activities

Environmental restoration and waste management activities at ORNL are the line responsibility of the Central Environmental Restoration Division and the Waste Management Organization of Lockheed Martin Energy Systems. Funding levels for environmental restoration and waste management are given in Table 6.4.

The Waste Management and Remedial Action Division (WMRAD) at ORNL is responsible for operation of all waste management facilities at ORNL (with the exception of the sanitary sewage system), as well as facility upgrades and construction of new waste management facilities. About 175 staff members are employed in the WMRAD. A number of other divisions and offices within ORNL and Energy Systems provide support to WMRAD activities.

Table 6.4
Environmental Management planned funding by fiscal year
(\$ in millions—BA)^a

	1995	1996	1997	1998	1999	2000	2001
EM Corrective Activities							
Operating	0.6	0.6	0.6	0.3	0.0	0.0	0.0
Capital equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Line item	26.1	4.3	2.7	0.0	0.0	0.0	0.0
Total	26.7	4.9	3.3	0.3	0.0	0.0	0.0
Environmental Restoration^b							
Operating	73.0	55.3	59.3	51.7	51.7	51.7	51.7
Capital equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	73.0	55.3	59.3	51.7	51.7	51.7	51.7
Nuclear Material and Facility Stabilization^c							
Operating	9.3	13.6	14.5	15.5	7.7	4.6	2.1
Line item	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	9.3	13.6	14.5	15.5	7.7	4.6	2.1
Waste Management							
Operating	50.6	49.8	53.5	40.8	40.9	41.1	41.1
Capital equipment	0.4	0.6	0.6	0.7	0.7	0.7	0.7
Construction	31.4	11.3	8.7	1.2	5.0	3.6	1.5
Total	82.4	61.7	62.8	42.7	46.6	45.4	43.3
Other^c							
Operating	4.2	4.2	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
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Total EM funding	195.6	139.7	144.1	114.1	110.2	105.9	101.3

^aOperating BA, capital equipment, construction, and proposed construction. These estimates reflect funding from Energy Systems central organizations, excluding Technology Development (EW40).

^bCosts for FY 1997–FY 2001 are estimates.

^cFunding included in the ORNL Financial Plan.

Environmental Restoration

Several hundred sites at ORNL are contaminated with radionuclides and hazardous chemicals. These sites include inactive underground waste storage tanks, leak and spill sites, radioactive waste burial grounds, and approximately 85 contaminated facilities (including five reactors) that require remedial actions. There is also significant contamination of surface water, groundwater, and biota. Multiple areas of contamination are connected within a complex geological and hydrological setting in which plumes have mingled, so remedial activities must consider surrounding and downgradient areas. A Federal Facilities Agreement (FFA) among DOE, the State of Tennessee, and the Environmental Protection Agency provides a framework for actions to protect human health and the environment, achieve compliance with environmental regulations, and meet public expectations.

The remedial action component of the Environmental Restoration Program addresses the investigation and remediation of the contaminated sites and contaminated environmental media at ORNL. Environmental data are collected in cooperation with other efforts at ORNL (e.g., the Environmental Compliance Program) with support from technical staff in the Environmental Sciences Division, Energy Division, and other ORNL organizations to address contaminant transport in the complex hydrogeologic setting at ORNL. Efforts to evaluate and remediate environmental problems build on research efforts at ORNL that are supported by DOE's Office of Energy Research and other basic science programs (see Sect. 5). The program also includes deactivation, surveillance and maintenance (S&M), and decontamination and decommissioning (D&D; here decommissioning is demolition or reuse) of contaminated surplus facilities.

Implementation Strategy

The strategy for implementing the ORNL Environmental Restoration Program includes the following steps:

1. Sites are prioritized for rapid actions based on human health and environmental risk. Rapid actions are taken to address contaminant releases and transport to off-site surface water and local groundwater. These must be consistent with likely future final actions. Monitoring at key locations quantifies and tracks contaminant releases and identifies major sources of contaminant release.
2. Remedial investigations are conducted to provide the information needed to formulate and implement final remedial actions. This step also includes working with stakeholders to establish land use objectives, conducting technology development activities, and performing feasibility studies.
3. Remediation is conducted to achieve the final goals for risk reduction and compliance with environmental regulations commensurate with planned or potential future land use.
4. Monitoring is continued at key locations to document the performance of remediation, evaluate the need for contingent actions, and identify remaining or new areas of concern.

Contaminated sites are prioritized for investigation and remediation on the basis of current and future risk to human health and the environment. Sites are prioritized for early actions based on potential off-site risk and for final actions based on potential future on-site risk to human health and the environment. Early actions for contaminant releases off-site have been initially prioritized on the basis of the contribution to the risk from water ingestion at White Oak Dam. Early actions are then taken to rapidly reduce these contaminant releases. Final actions have been prioritized on the basis of future potential on-site risk. This

prioritization was developed from contaminant inventories and potential hazard, and the ranking was modified by the potential for off-site release or on-site exposure resulting from failure of existing containment.

Inactive or Surplus Facilities

A number of facilities at ORNL have been declared inactive or surplus because the programs for which they were built have ended. There are currently about 100 inactive or surplus facilities. Some of these facilities contain substantial amounts of residual radioactive material. Because radioactivity could be released to the environment, plans are for these facilities to undergo D&D. Until D&D is complete, facilities 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. The objectives of the S&M program are to ensure adequate containment of residual radioactive and hazardous materials, to provide safety and security controls to minimize potential hazards to on-site personnel and the general public, and to cost-effectively manage surplus sites and facilities in compliance with applicable DOE Orders. 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.

A special element of the program is the deactivation and stabilization of inactive ORNL facilities for acceptance into DOE's Environmental Restoration Program. The Isotope Facilities Deactivation Project (IFDP) manages the activities required to place 19 inactive isotope production facilities in a radiologically and industrially safe condition for acceptance into DOE's Environmental Restoration Program. Similarly, the High Ranking Facilities Deactivation Project will stabilize four other ORNL facilities, including the Bulk Shielding Reactor and the Tower Shielding Reactor. The goal of these projects is to place all facilities in a condition such that (1) all stored radioactive materials, high-level radioactive wastes, and contaminated liquid waste have been removed; (2) the structures and radiation-monitoring systems are in a physical condition adequate to contain and to monitor any radioactive contamination in accordance with DOE Order 5480.1; (3) security systems and procedures are adequate to prevent unauthorized entry; and (4) all hazardous chemicals have been removed.

The budget for decommissioning of surplus facilities is highly variable and is subject to annual reprioritization to reflect facility conditions and ES&H risks, integration with remedial action at adjacent sites, and available funding. Budget requests for decommissioning of prioritized facilities at ORNL are submitted annually and included in the DOE Environmental Management Five-Year Plan. The budget for decommissioning surplus facilities was approximately \$12 million in FY 1995. Subsequent annual budgets are expected to increase during the planning period to keep pace with DOE's goals for site restoration. Near-term D&D projects will focus on removal of facilities in conjunction with regulatory-driven remediation of former waste management sites.

Planned Activities

Environmental restoration activities planned for FY 1996 include:

- continued monitoring and assessment of ORNL groundwater, surface water, and ecology,
- decision for the remediation of four radioactively contaminated surface water impoundments in the main plant area,
- demonstration of technologies for remote retrieval of radioactive sludges from large, 50-year-old underground storage tanks in the main plant area,
- action to mitigate ^{90}Sr releases from waste burial trenches in waste area grouping (WAG) 4,
- completion of in situ vitrification of radioactively contaminated soils in WAG 7,
- removal or closure of several small, inactive low-level liquid radioactive waste storage tanks,
- demolition of the inactive Waste Evaporator Facility,
- initiation of actions to remove 5000 gal of transuranic sludges from underground storage tanks at the old hydrofracture facility,
- plugging of wells that are conduits for contaminants moving from deep hydrofracture grout sheets to the near-surface water,
- deployment of a reactive gas removal system at the Molten Salt Reactor Experiment and continued planning for removal of uranium deposits and fuel salts,
- deactivation and stabilization of three isotope production facilities (Buildings 3028, 3029, and 7025), and
- initiation of planning and preparations for defueling the Bulk Shielding Reactor and the Tower Shielding Reactor.

Waste Management

The waste management program at ORNL provides continuous collection, treatment, and discharge of gaseous wastes; treats 535 million liters (150 million gal) per year of liquid radioactive waste (excluding sewage); and manages about 2,120 m³ (75,000 ft³) per year of solid radioactive, hazardous, mixed, and sanitary/industrial wastes. Major waste management activities include comprehensive coordination of waste reduction; integrated strategic and long-range planning; upgrades of existing facilities and construction of new ones; performance assessments of solid waste storage areas and other waste disposal facilities; waste collection and certification; and waste treatment, storage, and disposal.

Expense funding for waste management activities in FY 1996 is about \$50 million, including \$0.6 million for waste minimization (see Tables 6.3 and 6.4). The corrective activities component of the funding provides for implementation of the FFA requirements as they pertain to active low-level liquid waste (LLLW) tanks and tank systems. It also includes upgrades of the Bethel Valley and Melton Valley LLLW collection and transfer systems. Line item projects (see Table A.3 in the Appendix) include three projects for implementation of the active LLLW tank systems requirements of the FFA and one project for construction of the Melton Valley Storage Tanks Capacity Increase Project.

Out-year activities in waste management include continued operation of waste treatment, storage, and disposal facilities, with several upgrades. Additional reservation-wide facilities for waste management will be added to promote efficiency and improved ES&H conditions. Waste reduction will continue to be emphasized.

6.4 • Infrastructure and Support

6.4.1 • Capital Assets Planning

ORNL's programs require a variety of buildings and equipment, including specialized experimental laboratories, a large complement of office space, and major utility and waste disposal facilities. The Laboratory occupies 3,014,608 gross square feet (GSF) of building space at the main Bethel Valley site and the Melton Valley site to the south, 938,869 GSF of building space at the Oak Ridge Y-12 Plant, and 14,673 GSF of space at the Oak Ridge K-25 Site. ORNL also leases over 89,000 GSF of space off site. Distribution and use of space are described in the Appendix (see Figs. A.1–A.7 and Tables A.1 and A.2).

The Capital Assets Planning Group carries out efficient, state-of-the-art capital asset management and facility planning for ORNL. This group develops the Integrated Facilities Plan* (IFP) and site development plans. In addition, the Capital Assets Planning Group is ORNL's lead organization for DOE's Life-Cycle Asset Management process.

Life-Cycle Asset Management provides a means of monitoring the management of all assets owned by the government and managed by Lockheed Martin. Accurate and relevant information on all aspects of facility use is vital to the success of Life-Cycle Asset Management. Support for life-cycle asset management activities is provided by the DOE Multiprogram Energy Laboratories Facilities Support (MEL-FS) program (see Sect. 5.1.1.1).

The IFP defines ORNL's plans for facilities and site development. It also serves as a reference source for a broad base of site and facilities characterization data. Structured around a site development planning analysis, the IFP summarizes ORNL's present missions, programs, and population; reviews regional conditions; and describes site assets (land, buildings and other structures, utility distribution systems, transportation infrastructure, security and safety systems, and waste management systems).

An inventory of existing assets is provided. The construction projects required to support ORNL's future mission and program plans are described, and the impacts of these projects on the site's assets are summarized. Key elements of the site planning analysis are presented: assumptions and objectives for site development, an evaluation of the site for each objective, and alternatives for removing each site's deficiencies or excesses. A Master Plan for the site, with a 20- to 30-year time frame for full implementation, is developed and described. A review of the anticipated status of the site in ten years is presented to illustrate how the Master Plan is to be implemented.

The Capital Assets Planning Group is developing innovative management and planning tools to improve the accessibility of information. These tools include:

- The Integrated Laboratory Information System (ILIS), which provides a panoramic view of information related to capital asset and facility planning through a user-friendly software application. Modules are being developed to allow facility and Life-Cycle Asset Management managers to view stored information and to create information and organize it into projects.
- The Electronic Book IFP (EB-IFP). The IFP is available on compact disk (CD), which allows for mass storage and low-cost distribution of information.

*ORNL Integrated Facilities Plan, ORNL/PPA-94/2, Martin Marietta Energy Systems, Inc., April 1994. Also available on CD-ROM.

- The Space Allocation and Real Property Inventory System (SARPIS). SARPIS is an electronic database of facility information, updated annually by division space allocation managers and facility managers, that is the primary tool for analysis of how space is used at ORNL.
- Computer-based mapping. SARPIS is part of ORNL's Shared Data Initiative, which is using a commercial program (MapInfo®) and geographic information systems to make capital assets information readily available to users.

The Shared Data Initiative provides the focal point for the Capital Assets Planning Group's plans to integrate selected facility-related databases, correct discrepancies, and reduce duplication of effort in facility data collection. Plans call for incorporating the capital equipment inventory into the Shared Data Initiative.

Continuing efforts are needed to enable extensive renovations and rehabilitation of general-purpose buildings and utility systems that have deteriorated owing to insufficient capital improvement funding for modernization and adaptation to changing program needs. Increased DOE support for infrastructure improvements is improving the current situation. Several general-purpose office buildings have been constructed. A number of major construction line item projects are in the design/construction phase, including roof replacement, steam distribution system upgrade, sanitary sewer upgrade, and process waste treatment system upgrade. Funding received through the MEL-FS program is being applied to infrastructure needs.

However, additional funding is needed to bring buildings and utilities up to acceptable standards. The need to use general-purpose equipment (GPE) funding to meet high-priority compliance requirements related to replacement of chlorofluorocarbons (CFCs) and underground storage tanks means that GPE funding is not available for other needs.

ORNL is committed to good stewardship of its resources, both in management of existing facilities and in planning for future needs. The cost of construction and upgrades is being addressed through increased interactions with the construction manager. The Laboratory will prioritize its needs and apply resources as they become available to ensure that the maximum benefit is derived.

ORNL plans a vigorous program to manage and ultimately to renovate or dispose of facilities that have exceeded their useful life and that require continual S&M to ensure safe shutdown (see Sect. 6.3.3). Funding for this program of renovation and disposal will be supplied by the Office of Environmental Management and by the Inactive and Surplus Facilities subprogram (KG03) of the MEL-FS program. In FY 1995, this subprogram provided \$160,000 to remove contaminated equipment and refurbish a machinery maintenance facility for reuse. Figure A.8 shows anticipated/expected MEL-FS line item construction projects.

6.4.2 • Information Resource Management

ORNL increasingly recognizes the importance of information generated and used by all staff members. Timely and reliable information is critical to meeting objectives. The need for effective management of the large volume of information throughout ORNL has become vital. Steps are being taken to strengthen management attention to information as an asset and to improve user involvement in the effective use of information resources.

The management of information resources spans many areas—computing, telecommunications, records management, scientific and technical information, and printing and publishing. Scientific and technical information management at ORNL is described in

Sect. 5.1.6.2. The *Strategic Plan for Computing at Oak Ridge National Laboratory* (ORNL/PPA/INT-94/2, September 1994), which is summarized in Sect. 7, also contains goals directed toward improved information resource management (IRM).

The Laboratory's objectives for a coordinated IRM program include

- increased desktop access to information via Internet technologies;
- acquisition or development of tools, techniques and applications that support the information needs of ORNL;
- maximum participation in deployment of corporate applications to enable appropriate implementation for ORNL;
- efficient records management via efforts now under way to inventory and capture key attributes of archival records into electronic retrieval systems; and
- enhanced electronic distribution of documents (i.e., cradle-to-grave electronic publishing and dissemination).

ORNL has been an active participant in Energy Systems IRM initiatives, which span the Oak Ridge Complex. A Corporate Information Management Steering Council, composed of high-level representatives from the IRM service providers and each of the major Energy Systems business units, including ORNL, guides the evolution of the IRM program. The Steering Council will coordinate the efficient sharing of resources across Energy Systems. In the near term, benefits are expected to be realized by eliminating duplication of effort.

Effective IRM is a key to achieving an important Energy Systems management objective: the development of a more integrated and flexible company. Specific IRM plans for Energy Systems are detailed in two documents: *Martin Marietta Energy Systems FY 1997 Unicall Information Management Crosscut*, K/CSD/INF-95-1, and *Energy Systems Technical Architecture Specification*, ES/CIM-95/1.

6.5 • Communication and Trust

ORNL has made improved customer relationships one of its strategic goals (see Sect. 3.3.3). A number of activities—at local, state, and regional levels—support this goal. Included among these are the education and technology transfer efforts described elsewhere in this plan.

The Laboratory participates in community and regional affairs, both through participation of individual staff members and through direct institutional sponsorship of community and regional activities. Staff are encouraged, as individuals, to become involved in community governance and advice as appropriate to their technical or management expertise. For example, staff members serve on such organizations as the Environmental Quality Advisory Board and Transportation Safety Board of the City of Oak Ridge and on boards of directors for hospitals and service organizations.

ORNL staff are also active in local and regional units of professional societies that provide services to the community and region such as seminars, symposia, and career guidance. Some staff members participate in professional service organizations such as Rotary, with strong community interactions among local business and professional people. Others have become citizen activists for issues or events for which they have technical expertise or personal knowledge; examples include environmental quality, regional planning, community history celebrations, and industrial development.

At the Laboratory, ORNL hosts family and community days and encourages members of the community to visit. A combined Family Day and Community Day was held in October 1995. Laboratory staff also participate in educational fairs, environmental fairs, and other community events. Historical sites of technical and social significance, such as the Graphite Reactor and the New Bethel Church, are managed for visitation by the general public. Information about the environment of the Oak Ridge Reservation is disseminated to the public, and the public is involved in decisions concerning management of the reservation.

The Laboratory serves as a satellite center of the Oak Ridge Recording for the Blind and Dyslexic unit. Technically trained volunteer readers and monitors volunteer their time to produce scientific and technical materials for persons with perceptual disabilities, using facilities in the Central Research Library at ORNL.

The Tennessee Science and Technology Advisory Board assists the state in developing a science and technology policy. The ORNL Laboratory Director is a member of the Board, and a senior ORNL manager, on the staff of the Tennessee Commissioner for Community and Economic Development, provides support to the Board.

Communication of information about the Laboratory's programs, activities, and staff is a high priority. Information products include the *ORNL Review*, the Laboratory's R&D magazine; *ORNL 95*, the newest in a series reporting on science and technology at ORNL for general audiences; a set of brochures describing ORNL's R&D programs (one each for biotechnology, computing, energy, materials, environment, materials, and transportation); and a weekly column by the Laboratory Director for use by area newspapers. All of these information products are available electronically, in support of ORNL's plans, discussed in Sect. 5.1.6.2, to use the World Wide Web for communication about its research, technology, products, and services.

7 • Summaries of Other Plans

7.1 • Technology Transfer Plan

ORNL's technology transfer plan supports the emphasis placed on partnerships by the Department of Energy (DOE). Technology transfer efforts at the Laboratory have been a key component of the Lockheed Martin Energy Systems, Inc., technology transfer program, which focuses the resources of DOE's facilities in Oak Ridge on the technological challenges facing U.S. industry.

7.1.1 • Vision

The ORNL technology transfer program will set the standard for technology transfer from federal laboratories.

7.1.2 • Strategic Objectives

- The engineering and applied science infrastructure of ORNL, which has deteriorated with the decline of large programs, will be revitalized. A strong engineering and applied science base is an essential part of establishing and maintaining strong ties with industry.
- A vigorous personnel exchange program, including senior management, will be undertaken with industry to increase awareness in our staff of the industrial perspective and to acquaint industry with our capabilities.
- The development of specialized user centers having broad appeal to industry will be undertaken (see Sect. 5.1.7). Experience with the High Temperature Materials Laboratory demonstrates that access to moderately expensive and sophisticated laboratory equipment enhances competitiveness and attracts industry to the area.
- The role of ORNL in the Regional Assistance Program will be expanded.
- Strategic alliances with other national laboratories, industrial consortia, and universities will be expanded to provide stronger ORNL participation in major national initiatives.
- The ORNL program will be highly innovative. Appropriate metrics will be developed and tracked to refine our approach to existing activities.
- Legal and bureaucratic barriers will be eliminated to increase university and industrial participation in the full range of our programs.

7.1.3 • Resources and Staffing

The resources and staffing needed to implement Energy Systems technology transfer plans are listed in Table 7.1. The FY 1994 budget for the Energy Systems Office of Technology Transfer was \$4.3 million, supporting 37.3 full-time equivalent employees.

7.1.4 • Patents and Licensing

The Office of Technology Transfer continues to grow and improve the licensing/intellectual property of new technologies. In FY 1994, 121 patent applications were made, a 49% increase over FY 1993, and 23 licenses were executed, a 53% increase over FY 1993.

Program self-assessment and benchmarking against top universities and federal laboratories are leading to changes designed to strengthen the licensing program, such as (1) developing improved licensing strategy methods, (2) increasing the experience base of internal staff through workshops, intermediaries, and collaborative efforts, (3) encouraging entrepreneurial development, and (4) nurturing the licensee after completion of a deal.

Licenses executed in FY 1994 are listed in Table 7.2. Patent and licensing projections are presented in Table 7.3.

Table 7.1								
Technology transfer effort								
Estimated expenditures and staffing by fiscal year for the Office of Technology Transfer ^a								
	1994 ^b	1995	1996	1997	1998	1999	2000	2001
Funding (\$ in millions—BO)								
ORTA ^c activity	2.35	2.47	2.56	2.65	2.74	2.83	2.94	3.04
Patent/licensing activity	1.43	1.40	1.44	1.49	1.54	1.60	1.66	1.71
CRADA ^d funding								
Federal	24.76	33.92	38.32	39.66	41.05	42.49	43.97	45.50
Private industry	1.19	6.34	12.00	12.42	12.85	13.30	13.77	49.16
In kind ^e	25.64	39.78	49.73	51.47	53.27	55.14	57.07	59.06
Total	55.37	83.91	104.05	107.69	111.45	115.36	119.41	158.47
Professional staffing [full-time equivalent (FTE) employees]								
ORTA activity	24.5	23.4	24.0	24.0	24.0	24.0	24.0	24.0
Patent/licensing	7.8	7.6	7.6	7.6	7.6	7.6	7.6	7.6
CRADA activity	5.0	4.6	4.0	4.0	4.0	4.0	4.0	4.0
Total	37.3	35.6	35.6	35.6	35.6	35.6	35.6	35.6

^aData are for the Office of Technology Transfer, Lockheed Martin Energy Systems, Inc., which includes ORNL, the Oak Ridge Y-12 Plant, and the Oak Ridge K-25 Site.

^bActual.

^cOffice of Research and Technology Applications.

^dCooperative research and development agreement.

^eEstimated.

Table 7.2
Licensing summary
FY 1994

Licensee	Technology
3M	Ceramic fiber-reinforced filter
AlliedSignal	Gelcasting
Alpheus Cleaning Technologies Corp.	Cryoblasting process
Apocom, Inc.	GRAIL gene software
B&W Nuclear Service Company	Motor current signature analysis (8)
B&W Nuclear Technologies	Motor current signature analysis (4)
Chemrad Tennessee Corporation	Ultrasonic ranging and data telemetry
FMC Corporation, Lithium Division	Liquid surface skimmer for molten lithium and the like and method of use
Isotope Products Laboratories	Tungsten/rhenium radioisotope generator
ITI MOVATS	Method and apparatus for monitoring motor-operated valve motor output
ITI MOVATS, Inc.	Motor current signature analysis (11)
Lambda Technologies	Variable-frequency microwave furnace and method for processing of materials
Molecular Tool, Inc.	Microfluidics
Norm Smyrl and Associates	Infrared PCB spectral data
Open Range Software Corporation	Automated System for computer workstation adjustment
Open Range Software Corporation	Comprehensive tracking system
Photronix	Surface enhanced Raman optical data storage (SERODS) system
Powell River Laboratories	Non-lead environmentally safe projectiles
Public Service Electric and Gas Company	Motor monitoring method
Rapid Technologies, Inc.	Ductile aluminide alloys for high-temperature applications
RIS Corporation	Alpha/beta/gamma scintillation detector
World Library	Surface enhanced Raman optical data storage (SERODS) system

7.2 • Strategic Plan for Computing

The *Strategic Plan for Computing at Oak Ridge National Laboratory* (ORNL/PPA/INT-94/2, September 1994) describes ORNL's plans for computational science and the use of computing tools. A summary is presented here.

7.2.1 • Vision and Strategies

ORNL's overall vision in computing is to become a premier center for computational science, where computational scientists desire to work, and where outreach to industry and

Table 7.3
Patent and licensing projections by fiscal year^a

	1994 ^b	1995	1996	1997	1998
Patent applications	121	100	100	100	100
Patents granted	52	54	54	54	54
Product sales (in thousands of dollars)	12,641.7	16,000	20,800	29,120	43,680
Number of new licenses	23	30	40	50	60
License income (in thousands of dollars)	520.3	700	1,000	1,800	2,800
Use of income (in thousands of dollars)					
Employee awards	129.8	175.0	250.0	450.0	700.0
ORTA ^c office support	161.4	178.9	317.5	674.0	1,079.0
Other Lab R&D support	154.3	152.5	212.5	350.0	575.0
Federal income taxes	14.8	93.6	70.0	126.0	126.0
Technology transfer memberships	60.0	100.0	150.0	200.0	250.0

^aFunds are for the Office of Technology Transfer, Lockheed Martin Energy Systems, Inc., which includes ORNL, the Y-12 Plant, and the K-25 Site.

^bActual.

^cOffice of Research and Technology Applications.

education are central themes. Access to and manipulation of information on the desktop will become so easy that the computer will become the primary office tool for all ORNL staff.

To realize this vision, several long-term strategies have been identified. These strategies are organized into five areas: collaborations, computational sciences, high-performance computing and communications (HPCC) technologies, services, and user platforms.

Collaborations

Industry: ORNL will be a major partner with industry in projects that effectively transfer computing-related technologies to the private sector.

Education: While continuing its traditional strong involvement with undergraduate, graduate, and postgraduate education, ORNL will address lifelong learning through a focus on programs in education for students in kindergarten through high school.

Computational Sciences

In order to become a premier center for computational science, ORNL will focus on a few computational areas where it can build on existing strengths. The problems to be addressed will, in the main, be Grand Challenges, and emphasis will be placed on collaborative projects with, and in support of, industrial partners.

HPCC Technologies

ORNL will provide state-of-the-art HPCC support technologies to create a research ambiance to support the achievements of Grand Challenge computational science groups.

Computer hardware: ORNL will maintain its current leading position in obtaining high-performance research systems, developing systems, and production systems.

Data storage: ORNL will build on both current and planned storage experiments and systems to remain at the forefront of storage technology. ORNL will collaborate with industry and with other DOE laboratories in the use of these resources and this expertise.

Network research: ORNL will always have at least three technologies in the development queue: a research-level technology, a near-commercial technology, and a production-quality technology.

National Information Infrastructure (NII): ORNL will be a leader in the deployment of information infrastructure technology in the manipulation of large datasets, in collaboration with research partners, and in its daily research environment.

Algorithms: ORNL will be at the forefront in the development and analysis of numerical algorithms for solving large-scale scientific and engineering problems on advanced computer architectures. Emphasis will be on the transfer of this algorithmic technology to applications such as high-level interfaces and/or integration into software libraries.

Informatics: ORNL informatics research and development will expand significantly beyond the initial and continuing focus on genome informatics to address fundamental and applied problems in intelligent information processing.

Software tools: ORNL will continue to build on its world-wide reputation for developing quality software tools such as Parallel Virtual Machine (PVM), while expanding the scope of generically useful tools being developed, such as those for using large datasets.

Visualization: ORNL will stay at the cutting edge of this fast moving field, both in the development of emerging visualization technologies and in their application across computational disciplines. This will necessitate more attention to this field than has been given in the past.

Services

Information resource management (IRM): ORNL will have a coordinated program in which all ORNL staff have access to the information they need, when they need it, without concern for the source or the logistics of the information flow.

Production systems: Corporate administrative and operational information will be provided to users on their desktops in a user-friendly, client/server form based on open systems standards. Production UNIX environments will be available for scientific and technical computing users who do not have the necessary resources within their divisions.

Production networks: ORNL intends to continue to provide a high-speed fiber-optic backbone and connections to the Internet. Bridges, routers, network monitoring, and name service are provided. Services are provided to allow users to easily connect to this infrastructure via Ethernet or better.

Information servers: ORNL staff will have desktop computer access to management, compliance, scientific, engineering, and marketing information in immediately accessible, searchable, standard electronic form. Information server software to be used by a large population of clients should be designed with input from the user population. Seamless systems should be in place to allow for all ORNL employees to publish and provide electronic information that is accessible to computer users internal and external to Lockheed Martin Energy Systems, Inc.

User Platforms

ORNL will modernize its desktop computing and networking hardware and software to reduce overall cost and to facilitate information access and exchange.

7.2.2 • Goals

The following specific goals that support the vision and strategies in Sect. 7.3.1 are defined in the *Strategic Plan for Computing at Oak Ridge National Laboratory*.

Strategic area: **Collaborations**

Focus area: **Industry**

- Goal 1. Computational Center for Industrial Innovation (CCII) industrial interactions: Provide a hardware/software/collaborative environment through the CCII such that there are more than 12 industrial members by FY 1996.
- Goal 2. American Textile Partnership (AMTEX) cooperative R&D agreement: Demonstrate usage-driven manufacturing and replenishment of textile supplies for health care delivery applications. Demonstrate access, filtering, analysis, and effective feedback of point-of-sale information into the textile industry supply chain.
- Goal 3. Transportation collaborations: Establish a collaborative research environment in human-computer interactions for intelligent transportation systems. By FY 1996, establish collaborations in this area with at least six industry representatives.
- Goal 4. Gas and Oil NII collaboration: Achieve production runs of Institut Français du Pétrole seismic model on the Intel XP/S 35.

Strategic area: **Collaborations**

Focus area: **Education**

- Goal 5. CU-SeeMe experiment: Use Cornell University's CU-SeeMe software to allow a researcher at ORNL to give an interactive demonstration to up to eight remote sites via the Internet.
- Goal 6. Expansion of Adventures in Supercomputing (AiS) to middle schools: Select at least three middle schools for participation in AiS.

Strategic area: **Computational sciences**

- Goal 7. Materials: Develop tight-binding molecular dynamics production code for >2000 atoms with application to the phase diagram of carbon. Port large-scale ab initio pseudopotential production code to the Intel XP/S 35 with applications to metallic systems. Implement full-potential large-system multiple scattering method and produce production code for the XP/S 35.
- Goal 8. Groundwater: Incorporate into GCT code two-phase flow with relative permeabilities, additional chemical reactions, three-phase flow with relative permeabilities, and simple mass transfer between phases and components.

- Goal 9. Computer Hardware, Advanced Mathematics, and Model Physics (CHAMMP): Attain a high-resolution ("T170") climate simulation run covering 3 years with the PCCM2 code.

Strategic area: **HPC technologies**

Focus area: **Computer hardware**

- Goal 10. Massively parallel processing (MPP) upgrades: Bring the Intel Paragon XP/S 150 successfully through acceptance testing and into production, with application code performance consistent with machine capabilities.

Focus area: **Data storage**

- Goal 11. High-performance storage system: Install the parallel storage system HPSS as the controller for the ≈ 100 -terabyte Center for Computational Sciences/Atmospheric Radiation Measurement storage environment in FY1995.

Focus area: **Network research**

- Goal 12. Establish an ongoing research effort aimed at supporting the leading edge of production network technology and (through protocol development and similar research) complementing ORNL research in MPP computation.

Focus area: **National Information Infrastructure**

- Goal 13. Secure funding for one additional NII technology project.

Focus area: **Informatics**

- Goal 14. Bioscience: Develop tools for federation of biosciences databases.
Goal 15. Healthcare: Develop and evaluate intelligent tools for information processing and decision support in health care delivery applications.

Focus area: **Software tools**

- Goal 16. MPP software development: Establish four specific software development projects in FY 1995 with Intel and Kendall Square.

Focus area: **Visualization**

- Goal 17. Visualization research: Demonstrate a data-distributed visualization of a salt dome seismic dataset.
Goal 18. Coordination of visualization activities: Improve lab-wide communication/coordination of visualization activities through formation of an ORNL visualization steering group and through improved benchmarking with other national laboratories, universities, and research centers. Hold quarterly seminars to demonstrate new and existing visualization capabilities at ORNL.

Strategic area: **Services**

Focus area: **IRM**

- Goal 19. Information to the desktop: Acquire or develop tools, techniques and applications that support the information needs of ORNL.
Goal 20. Energy Systems corporate applications: Ensure maximum participation in deployment of corporate applications to enable appropriate implementation for ORNL.

Focus area: **Production systems**

- Goal 21. General-purpose MPP system: Acquire and put into production a high-performance, parallel, stable system for use by ORNL researchers.
- Goal 22. Open systems: Continue to move rapidly to production open systems compliant with de facto industry standards.

Focus area: **Production networks**

- Goal 23. Fiber-optic network extension: Install fiber from the existing fiber-optic backbone to major concentrations of users and systems. Develop an implementation plan for providing fiber to the desktop for all ORNL technical staff.

Focus area: **Information servers**

- Goal 24. Financial tools: Implement prototype financial tools for ORNL. These should be user-friendly, client/server implementations that allow project managers to obtain timely, accurate, and understandable financial data.

Strategic area: **User platforms**

- Goal 25. Upgrade to minimum user platform:
- Hardware: graphical user interface (GUI)-compatible desktop systems.
 - Network connection: Ethernet, fiber (FDDI), or better.
 - GUI: Microsoft Windows, Macintosh OS, or X Windows.
 - Mail: Standards-based desktop mail (MIME-compliant) system such as Eudora or Pine.
 - Software: Software and applications that are either market commodities or based on vendor-neutral standards. All staff should have World Wide Web, Gopher, Whos, Telnet, ftp, and NetNews.

8 • Resource Projections

The Laboratory's organization chart appears in the Appendix. Resource projections are presented in the following tables:

- Table 8.1, Laboratory funding summary,
- Table 8.2, Laboratory personnel summary,
- Table 8.3, funding by assistant secretarial level office,
- Table 8.4, personnel by assistant secretarial level office,
- Table 8.5, resources by program,
- Table 8.6, subcontracting and procurement, and
- Table 8.7, small and disadvantaged business procurement.

Tables 8.1, 8.3, 8.5, and 8.7 present resource projections for budget authority (BA) funding in millions of dollars. New BA requests are calculated by adding estimates of outstanding commitments and prefinancing to the total cost and then subtracting the prior-year uncoded budget. These resource projections reflect new BA funding requested in the FY 1996 budget submission documents, with some adjustments based on interim guidance. Planning for construction funding has not been completed beyond FY 1999. These projections do not include funds for the major initiatives proposed in Sect. 4 of this document.

Subcontracting and procurement funding is reported in Table 8.6 as total obligated funds for each fiscal year.

Personnel projections in Tables 8.2, 8.4, and 8.5 are given as the number of full-time equivalent (FTE) employees. These projections are based on funding requested in the FY 1996 budget submission documents, with some adjustments based on interim guidance.

Table 8.1
Laboratory funding summary by fiscal year
(\$ in millions—BA)

	1994	1995	1996	1997	1998	1999	2000	2001
DOE effort	491.8	493.3	478.4	489.6	489.6	489.6	489.6	489.6
Work for others	77.6	72.1	63.1	63.4	63.4	63.4	63.4	63.4
Total operating	569.4	565.4	541.5	553.0	553.0	553.0	553.0	553.0
Capital equipment	29.4	36.4	24.7	25.5	25.5	25.5	25.5	25.5
Construction	24.6	81.2	0.0	0.0	0.0	0.0	0.0	0.0
Total Laboratory	623.4	683.0	566.2	578.5	578.5	578.5	578.5	578.5
Proposed construction	—	—	43.5	42.8	33.9	27.2	25.0	25.0
Total projected funding	—	—	609.7	621.3	612.4	605.7	603.5	603.5

Table 8.2
Laboratory personnel summary by fiscal year^a
[Full-time equivalent (FTE) employees]

	1994	1995	1996	1997	1998	1999	2000	2001
Technical personnel, direct DOE effort	1538.4	1714.2	1735.5	1722.4	1722.4	1722.4	1722.4	1722.4
Technical personnel, Work for Others	304.1	308.5	287.2	275.0	275.0	275.0	275.0	275.0
Total technical direct personnel	1842.5	2022.7	2022.7	1997.4	1997.4	1997.4	1997.4	1997.4
Other direct	241.3	275.7	242.4	227.7	227.7	227.7	227.7	227.7
Total direct personnel	2083.8	2298.4	2265.1	2225.1	2225.1	2225.1	2225.1	2225.1
Indirect personnel	2692.7	2189.9	2144.0	2113.0	2069.0	2027.0	1987.0	1950.0
Total Laboratory	4776.5	4488.3	4409.1	4338.1	4294.1	4252.1	4212.1	4175.1

^aThese figures do not include Lockheed Martin Energy Systems central staff employees supported by ORNL.

Table 8.3
Funding by assistant secretarial level office by fiscal year
(\$ in millions—BA)

	1994	1995	1996	1997	1998	1999	2000	2001
<i>Science and Technology Programs</i>								
Office of Energy Research								
Operating expense	168.4	166.2	161.4	164.6	164.6	164.6	164.6	164.6
Capital equipment	17.1	14.3	15.5	16.8	16.8	16.8	16.8	16.8
Construction	9.1	9.9	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction	0.0	0.0	11.5	12.8	8.9	2.2	0.0	0.0
Total	194.6	190.4	188.4	194.2	190.3	183.6	181.4	181.4
Office of Nuclear Energy, Science and Technology								
Operating expense	18.6	19.5	22.8	22.7	22.7	22.7	22.7	22.7
Capital equipment	(0.3)	1.4	0.9	0.4	0.4	0.4	0.4	0.4
Total	18.3	20.9	23.7	23.1	23.1	23.1	23.1	23.1
Office of Science Education and Technical Information								
Operating expense	1.6	1.5	2.0	2.1	2.1	2.1	2.1	2.1
<i>Energy Programs</i>								
Office of Energy Efficiency and Renewable Energy								
Operating expense	77.6	88.2	91.2	97.0	97.0	97.0	97.0	97.0
Capital equipment	3.2	2.7	3.1	3.9	3.9	3.9	3.9	3.9
Total	80.8	90.9	94.3	100.9	100.9	100.9	100.9	100.9
Office of Fossil Energy								
Operating expense	10.1	8.8	10.9	11.6	11.6	11.6	11.6	11.6
Energy Information Administration								
Operating expense	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
<i>National Security and Environmental Management Programs</i>								
Office of Defense Programs								
Operating expense	11.2	12.6	13.3	13.5	13.5	13.5	13.5	13.5
Capital equipment	0.6	2.3	1.6	0.6	0.6	0.6	0.6	0.6
Construction	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0
Total	11.8	15.3	16.9	14.1	14.1	14.1	14.1	14.1
Office of Environmental Management								
Operating expense	4.7	4.7	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.9	24.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	5.6	28.7	0.0	0.0	0.0	0.0	0.0	0.0
Office of Fissile Materials Disposition								
Operating expense	0.0	4.3	4.9	4.9	4.9	4.9	4.9	4.9
Capital equipment	0.0	0.0	0.5	0.9	0.9	0.9	0.9	0.9
Total	0.0	4.3	5.4	5.8	5.8	5.8	5.8	5.8
Office of Civilian Radioactive Waste Management								
Operating expense	0.1	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Office of Nonproliferation and National Security								
Operating expense	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0

Table 8.3
(continued)

	1994	1995	1996	1997	1998	1999	2000	2001
<i>Other DOE Programs</i>								
Office of Environment, Safety, and Health								
Operating expense	13.8	12.5	11.9	13.5	13.5	13.5	13.5	13.5
Capital equipment	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Total	13.8	12.5	12.0	13.5	13.5	13.5	13.5	13.5
Office of Policy, Planning and Program Evaluation								
Operating expense	1.7	1.2	1.4	1.2	1.2	1.2	1.2	1.2
Office of the Associate Deputy Secretary for Field Management								
Operating expense	0.4	0.4	0.1	0.1	0.1	0.1	0.1	0.1
Construction	2.1	1.7	0.0	0.0	0.0	0.0	0.0	0.0
Total	2.5	2.1	0.1	0.1	0.1	0.1	0.1	0.1
Federal Energy Regulatory Commission								
Operating expense	2.2	0.6	1.0	0.0	0.0	0.0	0.0	0.0
Office of Human Resources and Administration								
Operating expense	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3
Office of Economic Impact and Diversity								
Operating expense	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0
DOE funding from Energy Systems central organizations								
Operating expense	159.8	153.6	140.0	140.0	140.0	140.0	140.0	140.0
Capital equipment	2.5	2.6	2.5	2.5	2.5	2.5	2.5	2.5
Construction	12.5	45.2	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction	0.0	0.0	30.0	30.0	25.0	25.0	25.0	25.0
Total	174.8	201.4	172.5	172.5	167.5	167.5	167.5	167.5
Subtotal DOE Programs								
Operating expense	471.0	475.0	461.8	472.1	472.1	472.1	472.1	472.1
Capital equipment	23.1	23.3	24.2	25.1	25.1	25.1	25.1	25.1
Construction	24.6	81.2	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction	0.0	0.0	43.5	42.8	33.9	27.2	25.0	25.0
Total	518.7	579.5	529.5	540.0	531.1	524.4	522.2	522.2
DOE Contractors and Operations Office								
Operating expense	20.8	18.3	16.6	17.5	17.5	17.5	19.3	19.3
Capital equipment	0.2	3.7	0.0	0.0	0.0	0.0	0.0	0.0
Total	21.0	22.0	16.6	17.5	17.5	17.5	19.3	19.3
Cooperative R&D Agreements								
Operating expense	0.6	0.7	1.3	1.2	1.2	1.2	1.2	1.2
Total DOE Programs								
Operating expense	491.8	493.3	478.4	489.6	489.6	489.6	489.6	489.6
Capital equipment	23.3	27.0	24.2	25.1	25.1	25.1	25.1	35.1
Construction	24.6	81.2	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction	0.0	0.0	43.5	42.8	33.9	27.2	25.0	25.0
Total	539.7	601.5	546.1	557.5	548.6	541.9	539.7	539.7

Table 8.3

(continued)

	1994	1995	1996	1997	1998	1999	2000	2001
Work for others								
Nuclear Regulatory Commission								
Operating expense	19.4	16.2	15.0	15.0	15.0	15.0	15.0	15.0
Capital equipment	0.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Total	19.9	16.4	15.0	15.0	15.0	15.0	15.0	15.0
Department of Defense								
Operating expense	22.2	25.5	22.4	24.4	24.4	24.4	24.4	24.4
Capital equipment	5.1	8.7	0.0	0.0	0.0	0.0	0.0	0.0
Total	27.3	34.2	22.4	24.4	24.4	24.4	24.4	24.4
National Aeronautics and Space Administration								
Operating expense	5.7	2.4	1.9	1.9	1.9	1.9	1.9	1.9
Department of Health and Human Services								
Operating expense	3.5	2.2	4.6	4.8	4.8	4.8	4.8	4.8
Environmental Protection Agency								
Operating expense	1.1	2.2	0.0	0.0	0.0	0.0	0.0	0.0
National Science Foundation								
Operating expense	0.1	0.0	0.5	0.5	0.5	0.5	0.5	0.5
Federal Emergency Management Agency								
Operating expense	2.0	1.6	2.6	1.3	1.3	1.3	1.3	1.3
Department of Transportation								
Operating expense	12.2	17.5	10.5	11.8	11.8	11.8	11.8	11.8
Capital equipment	0.2	0.3	0.4	0.3	0.3	0.3	0.3	0.3
Total	12.4	17.8	10.9	12.1	12.1	12.1	12.1	12.1
Other Federal agencies								
Operating expense	4.8	(3.4)	3.1	2.3	2.3	2.3	2.3	2.3
Capital equipment	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	5.0	(3.4)	3.1	2.3	2.3	2.3	2.3	2.3
Electric Power Research Institute								
Operating expense	1.8	1.4	1.0	0.5	0.5	0.5	0.5	0.5
Other nonfederal agencies								
Operating expense	4.8	6.5	1.5	0.9	0.9	0.9	0.9	0.9
Capital equipment	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Total	4.8	6.7	1.5	0.9	0.9	0.9	0.9	0.9
Total Work for Others								
Operating expense	77.6	72.1	63.1	63.4	63.4	63.4	63.4	63.4
Capital equipment	6.1	9.4	0.5	0.4	0.4	0.4	0.4	0.4
Total	83.7	81.5	63.6	63.8	63.8	63.8	63.8	63.8
Total Laboratory								
Operating expense	569.4	565.4	541.5	553.0	553.0	553.0	553.0	553.0
Capital equipment	29.4	36.4	24.7	25.5	25.5	25.5	25.5	25.5
Construction	24.6	81.2	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction	0.0	0.0	43.5	42.8	33.9	27.2	25.0	25.0
Total	623.4	683.0	609.7	621.3	612.4	605.7	603.5	603.5

Table 8.4
Personnel by assistant secretarial level office by fiscal year
 [Full-time equivalent (FTE) employees]

	1994	1995	1996	1997	1998	1999	2000	2001
Office of Energy Research								
Technical personnel	589.4	658.1	688.3	700.1	700.1	700.1	700.1	700.1
Other direct personnel	79.6	91.9	58.9	55.1	55.1	55.1	55.1	55.1
Total direct personnel	669.0	750.0	747.2	755.2	755.2	755.2	755.2	755.2
Office of Nuclear Energy, Science and Technology								
Technical personnel	66.7	49.2	54.9	51.6	51.6	51.6	51.6	51.6
Other direct personnel	0.7	1.7	4.9	2.7	2.7	2.7	2.7	2.7
Total direct personnel	67.4	50.9	59.8	54.3	54.3	54.3	54.3	54.3
Office of Science Education and Technical Information								
Technical personnel	3.3	2.4	4.3	4.6	4.6	4.6	4.6	4.6
Other direct personnel	0.2	0.4	0.3	0.3	0.3	0.3	0.3	0.3
Total direct personnel	3.5	2.8	4.6	4.9	4.9	4.9	4.9	4.9
Office of Energy Efficiency and Renewable Energy								
Technical personnel	178.3	180.9	192.5	189.5	189.5	189.5	189.5	189.5
Other direct personnel	9.1	14.3	5.3	5.5	5.5	5.5	5.5	5.5
Total direct personnel	187.4	195.2	197.8	195.0	195.0	195.0	195.0	195.0
Office of Fossil Energy								
Technical personnel	22.9	22.1	23.9	23.6	23.6	23.6	23.6	23.6
Other direct personnel	0.8	0.5	1.3	1.4	1.4	1.4	1.4	1.4
Total direct personnel	23.7	22.6	25.2	25.0	25.0	25.0	25.0	25.0
Energy Information Administration								
Technical personnel	0.9	1.3	0.3	0.1	0.1	0.1	0.1	0.1
Other direct personnel	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	0.9	1.4	0.3	0.1	0.1	0.1	0.1	0.1
Office of Defense Programs								
Technical personnel	42.8	44.6	44.4	43.4	43.4	43.4	43.4	43.4
Other direct personnel	2.3	3.9	4.1	3.6	3.6	3.6	3.6	3.6
Total direct personnel	45.1	48.5	48.5	47.0	47.0	47.0	47.0	47.0
Office of Environmental Management								
Technical personnel	24.0	33.0	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	2.2	0.7	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	26.2	33.7	0.0	0.0	0.0	0.0	0.0	0.0
Office of Fissile Materials Disposition								
Technical personnel	0.0	16.2	19.3	28.2	28.2	28.2	28.2	28.2
Other direct personnel	0.0	0.3	1.0	1.0	1.0	1.0	1.0	1.0
Total direct personnel	0.0	16.5	20.3	29.2	29.2	29.2	29.2	29.2
Office of Civilian Radioactive Waste Management								
Technical personnel	5.4	2.3	2.4	2.1	2.1	2.1	2.1	2.1
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	5.4	2.3	2.4	2.1	2.1	2.1	2.1	2.1
Office of Nonproliferation and National Security								
Technical personnel	0.4	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	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 8.4

(continued)

	1994	1995	1996	1997	1998	1999	2000	2001
Office of Environment, Safety, and Health								
Technical personnel	42.9	28.5	30.5	28.0	28.0	28.0	28.0	28.0
Other direct personnel	3.6	2.6	4.0	3.3	3.3	3.3	3.3	3.3
Total direct personnel	46.5	31.1	34.5	31.3	31.3	31.3	31.3	31.3
Office of Human Resources and Administration								
Technical personnel	0.9	0.2	1.0	1.0	1.0	1.0	1.0	1.0
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	0.9	0.2	1.0	1.0	1.0	1.0	1.0	1.0
Office of Policy, Planning and Program Evaluation								
Technical personnel	7.1	5.3	3.1	2.6	2.6	2.6	2.6	2.6
Other direct personnel	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	7.1	5.4	3.1	2.6	2.6	2.6	2.6	2.6
Federal Energy Regulatory Commission								
Technical personnel	5.2	5.0	7.4	0.0	0.0	0.0	0.0	0.0
Other direct personnel	0.8	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Total direct personnel	6.0	5.1	7.5	0.0	0.0	0.0	0.0	0.0
Associate Deputy Secretary for Field Management								
Technical personnel	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	2.1	3.8	1.6	0.3	0.3	0.3	0.3	0.3
Total direct personnel	2.1	9.8	1.6	0.3	0.3	0.3	0.3	0.3
Office of Economic Impact and Diversity								
Technical personnel	0.2	1.0	0.2	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	1.0	0.2	0.0	0.0	0.0	0.0	0.0
DOE funding from Energy Systems central organizations								
Technical personnel	484.5	598.2	618.5	623.8	623.8	623.8	623.8	623.8
Other direct personnel	102.3	122.1	120.7	126.6	126.6	126.6	126.6	126.6
Total direct personnel	586.8	720.3	739.2	750.4	750.4	750.4	750.4	750.4
Subtotal DOE Programs								
Technical personnel	1474.9	1654.3	1691.0	1698.6	1698.6	1698.6	1698.6	1698.6
Other direct personnel	203.7	242.5	202.2	199.8	199.8	199.8	199.8	199.8
Total direct personnel	1678.6	1896.8	1893.2	1898.4	1898.4	1898.4	1898.4	1898.4
DOE Contractors and Operations Office								
Technical personnel	63.5	59.9	44.5	23.8	23.8	23.8	23.8	23.8
Other direct personnel	11.0	12.3	19.9	15.3	15.3	15.3	15.3	15.3
Total direct personnel	74.5	72.2	64.4	39.1	39.1	39.1	39.1	39.1
Cooperative R&D Agreements								
Technical personnel	3.6	2.5	1.3	1.3	1.3	1.3	1.3	1.3
Other direct personnel	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	3.6	2.6	1.3	1.3	1.3	1.3	1.3	1.3
Total DOE Programs								
Technical personnel	1538.4	1714.2	1735.5	1722.4	1722.4	1722.4	1722.4	1722.4
Other direct personnel	214.7	254.8	222.1	215.1	215.1	215.1	215.1	215.1
Total direct personnel	1753.1	1969.0	1957.6	1937.5	1937.5	1937.5	1937.5	1937.5

Table 8.4

(continued)

	1994	1995	1996	1997	1998	1999	2000	2001
Work for others								
Nuclear Regulatory Commission								
Technical personnel	80.9	82.3	78.3	76.3	76.3	76.3	76.3	76.3
Other direct personnel	4.5	4.4	4.3	3.0	3.0	3.0	3.0	3.0
Total direct personnel	85.4	86.7	82.6	79.3	79.3	79.3	79.3	79.3
Department of Defense								
Technical personnel	121.5	117.9	95.3	90.1	90.1	90.1	90.1	90.1
Other direct personnel	20.1	10.5	12.4	6.6	6.6	6.6	6.6	6.6
Total direct personnel	141.6	128.4	107.7	96.7	96.7	96.7	96.7	96.7
National Aeronautics and Space Administration								
Technical personnel	12.9	7.6	7.2	6.4	6.4	6.4	6.4	6.4
Other direct personnel	0.3	0.6	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	13.2	8.2	7.2	6.4	6.4	6.4	6.4	6.4
Department of Health and Human Services								
Technical personnel	15.8	15.9	24.6	23.1	23.1	23.1	23.1	23.1
Other direct personnel	0.1	0.1	0.6	0.5	0.5	0.5	0.5	0.5
Total direct personnel	15.9	19.0	25.2	23.6	23.6	23.6	23.6	23.6
Environmental Protection Agency								
Technical personnel	10.4	15.0	1.3	0.0	0.0	0.0	0.0	0.0
Other direct personnel	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	10.5	15.1	1.3	0.0	0.0	0.0	0.0	0.0
National Science Foundation								
Technical personnel	3.2	0.4	1.0	1.0	1.0	1.0	1.0	1.0
Other direct personnel	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	3.4	0.4	1.0	1.0	1.0	1.0	1.0	1.0
Federal Emergency Management Agency								
Technical personnel	4.6	3.3	11.8	8.7	8.7	8.7	8.7	8.7
Other direct personnel	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	4.6	3.9	11.8	8.7	8.7	8.7	8.7	8.7
Department of Transportation								
Technical personnel	17.4	25.0	35.7	35.5	35.5	35.5	35.5	35.5
Other direct personnel	0.1	1.1	1.4	1.7	1.7	1.7	1.7	1.7
Total direct personnel	17.5	26.1	37.1	37.2	37.2	37.2	37.2	37.2
Other Federal agencies								
Technical personnel	10.9	13.5	16.8	25.5	25.5	25.5	25.5	25.5
Other direct personnel	0.3	0.9	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	11.2	14.4	16.8	25.5	25.5	25.5	25.5	25.5
Electric Power Research Institute								
Technical personnel	7.6	6.2	4.1	1.6	1.6	1.6	1.6	1.6
Other direct personnel	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Total direct personnel	7.7	6.4	4.3	1.8	1.8	1.8	1.8	1.8
Other nonfederal agencies								
Technical personnel	18.9	21.4	11.1	6.8	6.8	6.8	6.8	6.8
Other direct personnel	0.8	2.4	1.4	0.6	0.6	0.6	0.6	0.6
Total direct personnel	19.7	23.8	12.5	7.4	7.4	7.4	7.4	7.4

Table 8.4

(continued)

	1994	1995	1996	1997	1998	1999	2000	2001
Total Work for Others								
Technical personnel	304.1	308.5	287.2	275.0	275.0	275.0	275.0	275.0
Other direct personnel	26.6	20.9	20.3	12.6	12.6	12.6	12.6	12.6
Total direct personnel	330.7	329.4	307.5	287.6	287.6	287.6	287.6	287.6
Total Laboratory								
Technical personnel	1842.5	2022.7	2022.7	1997.4	1997.4	1997.4	1997.4	1997.4
Other direct personnel	241.3	275.7	242.4	227.7	227.7	227.7	227.7	227.7
Total Laboratory direct personnel	2083.8	2298.4	2265.1	2225.1	2225.1	2225.1	2225.1	2225.1
Total Laboratory indirect personnel	2692.7	2189.9	2144.0	2113.0	2069.0	2027.0	1987.0	1950.0
Total Laboratory personnel	4776.5	4488.3	4409.1	4338.1	4294.1	4252.1	4212.1	4175.1

Table 8.5
Resources by program by fiscal year
(\$ in millions)

	1994	1995	1996	1997	1998	1999	2000	2001
Office of Energy Research								
Magnetic Fusion—AT								
Total operating	29.8	27.1	26.6	26.6	26.6	26.6	26.6	26.6
Capital equipment	1.6	1.0	1.5	1.5	1.5	1.5	1.5	1.5
Total program	31.4	28.1	28.1	28.1	28.1	28.1	28.1	28.1
Technical personnel	91.7	87.8	89.4	87.3	87.3	87.3	87.3	87.3
Other direct personnel	26.0	24.8	24.3	24.7	24.7	24.7	24.7	24.7
Total direct personnel	117.7	112.6	113.7	112.0	112.0	112.0	112.0	112.0
High Energy Physics—KA								
Total operating	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Capital equipment	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total program	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3
Technical personnel	1.7	1.4	1.5	1.5	1.5	1.5	1.5	1.5
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	1.7	1.4	1.5	1.5	1.5	1.5	1.5	1.5
Nuclear Physics—KB								
Total operating	9.6	10.6	11.8	14.8	14.8	14.8	14.8	14.8
Capital equipment	2.3	1.6	2.2	2.4	2.4	2.4	2.4	2.4
Construction	1.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0
Total program	12.9	12.4	14.8	17.2	17.2	17.2	17.2	17.2
Technical personnel	41.8	58.0	51.0	61.3	61.3	61.3	61.3	61.3
Other direct personnel	0.1	0.7	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	41.9	58.7	51.0	61.3	61.3	61.3	61.3	61.3
Basic Energy Sciences—KC								
Total operating	80.8	78.0	79.6	78.0	78.0	78.0	78.0	78.0
Capital equipment	6.3	5.4	4.8	4.1	4.1	4.1	4.1	4.1
Construction	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction	0.0	0.0	1.2	3.7	0.0	0.0	0.0	0.0
Total program	87.6	83.4	85.6	85.8	82.1	82.1	82.1	82.1
Technical personnel	302.5	329.6	375.5	375.8	375.8	375.8	375.8	375.8
Other direct personnel	11.0	15.3	14.1	12.2	12.2	12.2	12.2	12.2
Total direct personnel	313.5	344.9	389.6	388.0	388.0	388.0	388.0	388.0
Energy Research Analyses—KD								
Total operating	0.7	0.6	1.6	1.6	1.6	1.6	1.6	1.6
Technical personnel	2.8	2.6	2.0	2.0	2.0	2.0	2.0	2.0
Other direct personnel	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	2.8	2.7	2.0	2.0	2.0	2.0	2.0	2.0
Advanced Neutron Source—KE								
Total operating	15.5	12.8	0.0	0.0	0.0	0.0	0.0	0.0
Technical personnel	41.7	37.1	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	38.0	28.7	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	79.7	65.8	0.0	0.0	0.0	0.0	0.0	0.0

Table 8.5

(continued)

	1994	1995	1996	1997	1998	1999	2000	2001
Multiprogram Energy Laboratory—Facility Support—KG								
Total operating	0.6	2.5	5.0	5.7	5.7	5.7	5.7	5.7
Capital equipment	5.9	5.5	6.0	5.8	5.8	5.8	5.8	5.8
Construction (MGPF)	7.6	9.7	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction	0.0	0.0	9.5	9.1	8.9	2.2	0.0	0.0
Total program	14.1	17.7	20.5	20.6	20.4	13.7	11.5	11.5
Technical personnel	2.2	19.3	34.0	35.9	35.9	35.9	35.9	35.9
Other direct personnel	0.3	16.9	17.8	15.5	15.5	15.5	15.5	15.5
Total direct personnel	2.5	36.2	51.8	51.4	51.4	51.4	51.4	51.4
Biological and Environmental Research—KP								
Total operating	25.9	23.5	24.2	25.3	25.3	25.3	25.3	25.3
Capital equipment	1.0	0.7	1.0	3.0	3.0	3.0	3.0	3.0
Total program	26.9	24.2	25.2	28.3	28.3	28.3	28.3	28.3
Technical personnel	92.9	90.6	100.4	100.1	100.1	100.1	100.1	100.1
Other direct personnel	4.0	3.7	2.7	2.7	2.7	2.7	2.7	2.7
Total direct personnel	96.9	94.3	103.1	102.8	102.8	102.8	102.8	102.8
Superconducting Super Collider—KS								
Total operating	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Technical personnel	1.4	1.0	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	1.4	1.0	0.0	0.0	0.0	0.0	0.0	0.0
Technology Transfer—KU								
Total operating	5.0	10.7	12.3	12.3	12.3	12.3	12.3	12.3
Technical personnel	10.7	30.7	34.5	36.2	36.2	36.2	36.2	36.2
Other direct personnel	0.2	1.5	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	10.9	32.2	34.5	36.2	36.2	36.2	36.2	36.2
Total Office of Energy Research								
Operating expense	168.4	166.2	161.4	164.6	164.6	164.6	164.6	164.6
Capital equipment	17.1	14.3	15.5	16.8	16.8	16.8	16.8	16.8
Construction	9.1	9.9	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction	0.0	0.0	11.5	12.8	8.9	2.2	0.0	0.0
Total program	194.6	190.4	188.4	194.2	190.3	183.6	181.4	181.4
Technical personnel	589.4	658.1	688.3	700.1	700.1	700.1	700.1	700.1
Other direct personnel	79.6	91.9	58.9	55.1	55.1	55.1	55.1	55.1
Total direct personnel	669.0	750.0	747.2	755.2	755.2	755.2	755.2	755.2
Office of Nuclear Energy, Science and Technology								
Nuclear Energy R&D—AF								
Total operating	10.8	7.9	7.8	8.5	8.5	8.5	8.5	8.5
Capital equipment	(0.3)	1.1	0.8	0.3	0.3	0.3	0.3	0.3
Total program	10.5	9.0	8.6	8.8	8.8	8.8	8.8	8.8
Technical personnel	53.8	35.6	36.2	34.7	34.7	34.7	34.7	34.7
Other direct personnel	0.7	1.5	3.3	1.7	1.7	1.7	1.7	1.7
Total direct personnel	54.5	37.1	39.5	36.4	36.4	36.4	36.4	36.4
Naval Reactors—AJ								
Total operating	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Technical personnel	0.5	0.3	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	0.5	0.3	0.4	0.4	0.4	0.4	0.4	0.4

Table 8.5
(continued)

	1994	1995	1996	1997	1998	1999	2000	2001
Uranium Enrichment—CD								
Total operating	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital equipment	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Total program	0.0	2.2	0.0	0.0	0.0	0.0	0.0	0.0
Technical personnel	0.4	0.6	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	0.4	0.6	0.0	0.0	0.0	0.0	0.0	0.0
Policy and Management—Nuclear Energy—KK								
Total operating	0.6	0.0	0.2	0.2	0.2	0.2	0.2	0.2
Technical personnel	2.7	0.5	1.5	1.2	1.2	1.2	1.2	1.2
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	2.7	0.5	1.5	1.2	1.2	1.2	1.2	1.2
Isotope Production and Distribution Program—ST								
Total operating	7.1	9.5	14.7	13.9	13.9	13.9	13.9	13.9
Capital equipment	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total program	7.1	9.6	14.8	14.0	14.0	14.0	14.0	14.0
Technical personnel	9.3	12.2	16.8	15.3	15.3	15.3	15.3	15.3
Other direct personnel	0.0	0.2	1.6	1.0	1.0	1.0	1.0	1.0
Total direct personnel	9.3	12.4	18.4	16.3	16.3	16.3	16.3	16.3
Total Office of Nuclear Energy, Science and Technology								
Operating expense	18.6	19.5	22.8	22.7	22.7	22.7	22.7	22.7
Capital equipment	(0.3)	1.4	0.9	0.4	0.4	0.4	0.4	0.4
Total program	18.3	20.9	23.7	23.1	23.1	23.1	23.1	23.1
Technical personnel	66.7	49.2	54.9	51.6	51.6	51.6	51.6	51.6
Other direct personnel	0.7	1.7	4.9	2.7	2.7	2.7	2.7	2.7
Total direct personnel	67.4	50.9	59.8	54.3	54.3	54.3	54.3	54.3
Office of Science Education and Technical Information								
University & Science Education—KT								
Total operating	1.6	1.6	2.0	2.1	2.1	2.1	2.1	2.1
Technical personnel	2.3	2.3	4.3	4.6	4.6	4.6	4.6	4.6
Other direct personnel	0.1	0.4	0.3	0.3	0.3	0.0	0.3	0.0
Total direct personnel	2.4	2.7	4.6	4.9	4.9	4.9	4.9	4.9
University & Science Education—KV								
Total operating	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Technical personnel	1.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	1.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total Office of Science Education and Technical Information								
Total operating	1.6	1.6	2.0	2.1	2.1	2.1	2.1	2.1
Technical personnel	3.3	2.4	4.3	4.6	4.6	4.6	4.6	4.6
Other direct personnel	0.2	0.4	0.3	0.3	0.3	0.0	0.3	0.0
Total direct personnel	3.5	2.8	4.6	4.9	4.9	4.9	4.9	4.9

Table 8.5
(continued)

	1994	1995	1996	1997	1998	1999	2000	2001
Office of Energy Efficiency and Renewable Energy								
Electric Energy Systems—AK								
Total operating	13.1	12.5	16.9	18.7	18.7	18.7	18.7	18.7
Capital equipment	0.3	0.0	0.3	0.3	0.3	0.3	0.3	0.3
Total program	13.4	12.5	17.2	19.0	19.0	19.0	19.0	19.0
Technical personnel	28.4	26.1	28.5	30.7	30.7	30.7	30.7	30.7
Other direct personnel	0.7	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Total direct personnel	29.1	28.3	30.7	32.9	32.9	32.9	32.9	32.9
Geothermal Energy —AM								
Total operating	0.7	(0.7)	0.5	0.5	0.5	0.5	0.5	0.5
Technical personnel	3.4	0.3	2.2	2.3	2.3	2.3	2.3	2.3
Other direct personnel	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	3.5	0.3	2.2	2.3	2.3	2.3	2.3	2.3
Hydrogen Research—AR								
Total operating	0.4	0.4	2.8	1.4	1.4	1.4	1.4	1.4
Capital equipment	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Total program	0.4	0.4	2.9	1.5	1.5	1.5	1.5	1.5
Technical personnel	0.8	2.9	4.3	5.4	5.4	5.4	5.4	5.4
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	0.8	2.9	4.3	5.4	5.4	5.4	5.4	5.4
Hydropower—CE								
Total operating	0.3	0.1	0.5	0.5	0.5	0.5	0.5	0.5
Technical personnel	0.7	0.6	2.3	2.4	2.4	2.4	2.4	2.4
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	0.7	0.6	2.3	2.4	2.4	2.4	2.4	2.4
Solar Energy—EB								
Total operating	4.8	4.8	4.8	4.6	4.6	4.6	4.6	4.6
Capital equipment	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Total program	4.9	5.0	5.0	4.8	4.8	4.8	4.8	4.8
Technical personnel	11.6	11.7	12.0	12.0	12.0	12.0	12.0	12.0
Other direct personnel	0.9	0.9	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	12.5	12.6	12.0	12.0	12.0	12.0	12.0	12.0
Buildings Sector—EC								
Total operating	14.2	18.4	17.6	17.6	17.6	17.6	17.6	17.6
Capital equipment	0.4	0.7	0.7	0.9	0.9	0.9	0.9	0.9
Total program	14.6	19.1	18.3	18.5	18.5	18.5	18.5	18.5
Technical personnel	37.6	34.1	35.0	31.6	31.6	31.6	31.6	31.6
Other direct personnel	3.3	3.0	1.3	1.1	1.1	1.1	1.1	1.1
Total direct personnel	40.9	37.1	36.3	32.7	32.7	32.7	32.7	32.7
Industrial Sector—ED								
Total operating	11.8	14.7	13.9	15.7	15.7	15.7	15.7	15.7
Capital equipment	0.5	1.4	0.6	0.4	0.4	0.4	0.4	0.4
Total program	12.3	16.1	14.5	16.1	16.1	16.1	16.1	16.1
Technical personnel	30.6	34.9	37.8	38.3	38.3	38.3	38.3	38.3
Other direct personnel	0.9	2.9	0.3	0.2	0.2	0.2	0.2	0.2
Total direct personnel	31.5	37.8	38.1	38.5	38.5	38.5	38.5	38.5

Table 8.5

(continued)

	1994	1995	1996	1997	1998	1999	2000	2001
Transportation Sector—EE								
Total operating	29.7	34.9	31.2	34.4	34.4	34.4	34.4	34.4
Capital equipment	1.9	0.4	1.2	2.0	2.0	2.0	2.0	2.0
Total program	31.6	35.3	32.4	36.4	36.4	36.4	36.4	36.4
Technical personnel	55.4	57.9	58.4	55.8	55.8	55.8	55.8	55.8
Other direct personnel	2.4	4.4	1.0	1.6	1.6	1.6	1.6	1.6
Total direct personnel	57.8	62.3	59.4	57.4	57.4	57.4	57.4	57.4
Technical and Financial Assistance—EF								
Total operating	1.6	1.7	1.6	2.1	2.1	2.1	2.1	2.1
Technical personnel	4.6	5.9	5.7	5.3	5.3	5.3	5.3	5.3
Other direct personnel	0.7	0.8	0.5	0.4	0.4	0.4	0.4	0.4
Total direct personnel	5.3	6.7	6.2	5.7	5.7	5.7	5.7	5.7
Policy and Management—EH								
Total operating	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Technical personnel	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Utility Sector—EK								
Total operating	1.0	1.4	1.4	1.5	1.5	1.5	1.5	1.5
Technical personnel	5.2	6.3	6.3	5.7	5.7	5.7	5.7	5.7
Other direct personnel	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	5.3	6.4	6.3	5.7	5.7	5.7	5.7	5.7
Total Office of Energy Efficiency and Renewable Energy								
Operating expense	77.6	88.2	91.2	97.0	97.0	97.0	117.0	117.0
Capital equipment	3.2	2.7	3.1	3.9	3.9	3.9	3.9	3.9
Total	80.8	90.9	94.3	100.9	100.9	100.9	100.9	100.9
Technical personnel	178.3	180.9	192.5	189.5	189.5	189.5	189.5	189.5
Other direct personnel	9.1	14.3	5.3	5.5	5.5	5.5	5.5	5.5
Total direct personnel	187.4	195.2	197.8	195.0	195.0	195.0	195.0	195.0
Office of Fossil Energy								
Coal—AA								
Total operating	7.9	6.7	7.9	8.2	8.2	8.2	8.2	8.2
Technical personnel	18.0	18.1	18.8	19.3	19.3	19.3	19.3	19.3
Other direct personnel	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	18.1	18.4	18.8	19.3	19.3	19.3	19.3	19.3
Gas—AB								
Total operating	1.0	1.0	1.3	1.5	1.5	1.5	1.5	1.5
Technical personnel	0.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	0.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Petroleum—AC								
Total operating	0.0	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Technical personnel	0.8	1.8	1.7	1.6	1.6	1.6	1.6	1.6
Other direct personnel	0.0	0.0	1.3	1.4	1.4	1.4	1.4	1.4
Total direct personnel	0.8	1.8	3.0	3.0	3.0	3.0	3.0	3.0

Table 8.5
(continued)

	1994	1995	1996	1997	1998	1999	2000	2001
Fossil Energy Environmental Restoration—AW								
Total operating	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Technical personnel	0.1	0.1	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	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Innovative Clean Coal Technology—AZ								
Total operating	1.1	0.2	0.7	0.9	0.9	0.9	0.9	0.9
Technical personnel	2.7	0.7	1.7	1.0	1.0	1.0	1.0	1.0
Other direct personnel	0.7	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	3.4	0.9	1.7	1.0	1.0	1.0	1.0	1.0
Strategic Petroleum Reserve—SA								
Total operating	0.0	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Technical personnel	1.1	0.9	1.2	1.2	1.2	1.2	1.2	1.2
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	1.1	0.9	1.2	1.2	1.2	1.2	1.2	1.2
Total Office of Fossil Energy								
Total operating	10.1	8.8	10.9	11.6	11.6	11.6	11.6	11.6
Technical personnel	22.9	22.1	23.9	23.6	23.6	23.6	23.6	23.6
Other direct personnel	0.8	0.5	1.3	1.4	1.4	1.4	1.4	1.4
Total direct personnel	23.7	22.6	25.2	25.0	25.0	25.0	25.0	25.0
Energy Information Administration								
National Energy Information System—TA								
Total operating	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Technical personnel	0.9	1.3	0.3	0.1	0.1	0.1	0.1	0.1
Other direct personnel	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	0.9	1.4	0.3	0.1	0.1	0.1	0.1	0.1
Total Energy Information Administration								
Operating expense	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Technical personnel	0.9	1.3	0.3	0.1	0.1	0.1	0.1	0.1
Other direct personnel	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	0.9	1.4	0.3	0.1	0.1	0.1	0.1	0.1
Office of Defense Programs								
Weapons Activities—GB								
Operating expense	1.0	0.6	0.4	0.4	0.4	0.4	0.4	0.4
Capital equipment	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Total operating	1.0	0.6	0.5	0.4	0.4	0.4	0.4	0.4
Technical personnel	4.1	3.0	2.3	2.2	2.2	2.2	2.2	2.2
Other direct personnel	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	4.3	3.0	2.3	2.2	2.2	2.2	2.2	2.2
Materials Production—GE								
Total operating	9.5	12.0	12.9	13.1	13.1	13.1	13.1	13.1
Capital equipment	0.5	2.4	1.5	0.6	0.6	0.6	0.6	0.6
Construction	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0
Total program	10.0	14.8	16.4	13.7	13.7	13.7	13.7	13.7
Technical personnel	38.2	41.5	42.1	41.2	41.2	41.2	41.2	41.2
Other direct personnel	2.1	3.9	4.1	3.6	3.6	3.6	3.6	3.6
Total direct personnel	40.3	45.4	46.2	44.8	44.8	44.8	44.8	44.8

Table 8.5

(continued)

	1994	1995	1996	1997	1998	1999	2000	2001
New Production Reactors—NP								
Total operating	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital equipment	0.1	(0.1)	0.0	0.0	0.0	0.0	0.0	0.0
Total program	0.8	(0.1)	0.0	0.0	0.0	0.0	0.0	0.0
Technical personnel	0.5	0.1	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	0.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total Office of Defense Programs								
Total operating	11.2	12.6	13.3	13.5	13.5	13.5	13.5	13.5
Capital equipment	0.6	2.3	1.6	0.6	0.6	0.6	0.6	0.6
Proposed construction	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0
Total program	11.8	15.3	16.9	14.1	14.1	14.1	14.1	14.1
Technical personnel	42.8	44.6	44.4	43.4	43.4	43.4	43.4	43.4
Other direct personnel	2.3	3.9	4.1	3.6	3.6	3.6	3.6	3.6
Total direct personnel	45.1	48.5	48.5	47.0	47.0	47.0	47.0	47.0
Office of Environmental Management								
Environmental Restoration and Waste Management—Defense—EW								
Total operating	1.2	1.5	0.0	0.0	0.0	0.0	0.0	0.0
Construction	(2.3)	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total program	(1.1)	1.6	0.0	0.0	0.0	0.0	0.0	0.0
Technical personnel	9.4	9.1	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	0.7	0.5	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	10.1	9.6	0.0	0.0	0.0	0.0	0.0	0.0
Environmental Restoration and Waste Management—Non-Defense—EX								
Total operating	3.5	3.2	0.0	0.0	0.0	0.0	0.0	0.0
Construction (GPP)	3.2	23.9	0.0	0.0	0.0	0.0	0.0	0.0
Total program	6.7	27.1	0.0	0.0	0.0	0.0	0.0	0.0
Technical personnel	14.6	23.9	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	1.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	16.1	24.1	0.0	0.0	0.0	0.0	0.0	0.0
Total Office of Environmental Management								
Total operating	4.7	4.7	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.9	24.0	0.0	0.0	0.0	0.0	0.0	0.0
Total program	5.6	28.7	0.0	0.0	0.0	0.0	0.0	0.0
Technical personnel	24.0	33.0	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	2.2	0.7	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	26.2	33.7	0.0	0.0	0.0	0.0	0.0	0.0

Table 8.5

(continued)

	1994	1995	1996	1997	1998	1999	2000	2001
Office of Fissile Materials Disposition								
Fissile Materials Disposition—GA								
Total operating	0.0	4.3	4.9	4.9	4.9	4.9	4.9	4.9
Capital equipment	0.0	0.0	0.5	0.9	0.9	0.9	0.9	0.9
Total program	0.0	4.3	5.4	5.8	5.8	5.8	5.8	5.8
Technical personnel	0.0	16.2	19.3	28.2	28.2	28.2	28.2	28.2
Other direct personnel	0.0	0.3	1.0	1.0	1.0	1.0	1.0	1.0
Total direct personnel	0.0	16.5	20.3	29.2	29.2	29.2	29.2	29.2
Total Office of Fissile Materials Disposition								
Total operating	0.0	4.3	4.9	4.9	4.9	4.9	4.9	4.9
Capital equipment	0.0	0.0	0.5	0.9	0.9	0.9	0.9	0.9
Total program	0.0	4.3	5.4	5.8	5.8	5.8	5.8	5.8
Technical personnel	0.0	16.2	19.3	28.2	28.2	28.2	28.2	28.2
Other direct personnel	0.0	0.3	1.0	1.0	1.0	1.0	1.0	1.0
Total direct personnel	0.0	16.5	20.3	29.2	29.2	29.2	29.2	29.2
Office of Civilian Radioactive Waste Management								
Nuclear Waste Fund—DB								
Total operating	0.1	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Technical personnel	5.4	2.3	2.4	2.1	2.1	2.1	2.1	2.1
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	5.4	2.3	2.4	2.1	2.1	2.1	2.1	2.1
Total Office of Civilian Radioactive Waste Management								
Total operating	0.1	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Technical personnel	5.4	2.3	2.4	2.1	2.1	2.1	2.1	2.1
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	5.4	2.3	2.4	2.1	2.1	2.1	2.1	2.1
Office of Nonproliferation and National Security								
Nuclear Safeguards and Security—GD								
Total operating	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Technical personnel	0.3	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	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Emergency Preparedness—NB								
Total operating	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Technical personnel	0.1	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	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Office of Nonproliferation and National Security								
Total operating	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Technical personnel	0.4	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	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 8.5
(continued)

	1994	1995	1996	1997	1998	1999	2000	2001
Office of Environment, Safety, and Health								
Environmental Research and Development—HA								
Total operating	10.8	10.3	9.9	11.7	11.7	11.7	11.7	11.7
Capital equipment	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Total program	10.8	10.3	10.0	11.7	11.7	11.7	11.7	11.7
Technical personnel	33.0	21.3	23.8	21.9	21.9	21.9	21.9	21.9
Other direct personnel	1.5	1.9	0.2	0.2	0.2	0.2	0.2	0.2
Total direct personnel	34.5	23.2	24.0	22.1	22.1	22.1	22.1	22.1
Nuclear Safety Policy—HP								
Total operating	3.2	2.1	1.9	1.7	1.7	1.7	1.7	1.7
Technical personnel	8.1	7.1	6.5	5.9	5.9	5.9	5.9	5.9
Other direct personnel	1.9	0.7	3.8	3.1	3.1	3.1	3.1	3.1
Total direct personnel	10.0	7.8	10.3	9.0	9.0	9.0	9.0	9.0
Epidemiological Activities—HR								
Total operating	0.0	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	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Office of Nuclear Safety—NS								
Total operating	(0.2)	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Technical personnel	1.6	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Other direct personnel	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	1.7	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Total Office of Environment, Safety, and Health								
Total operating	13.8	12.5	11.9	13.5	13.5	13.5	13.5	13.5
Capital equipment	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Total program	13.8	12.5	12.0	13.5	13.5	13.5	13.5	13.5
Technical personnel	42.9	28.5	30.5	28.0	28.0	28.0	28.0	28.0
Other direct personnel	3.6	2.6	4.0	3.3	3.3	3.3	3.3	3.3
Total direct personnel	46.5	31.1	34.5	31.3	31.3	31.3	31.3	31.3
Office of Human Resources and Administration								
Scientific and Engineering Recruitment, T&D—TR								
Total operating	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3
Technical personnel	0.9	0.2	1.0	1.0	1.0	1.0	1.0	1.0
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	0.9	0.2	1.0	1.0	1.0	1.0	1.0	1.0
Total Office of Human Resources and Administration								
Total operating	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3
Technical personnel	0.9	0.2	1.0	1.0	1.0	1.0	1.0	1.0
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	0.9	0.2	1.0	1.0	1.0	1.0	1.0	1.0

Table 8.5

(continued)

	1994	1995	1996	1997	1998	1999	2000	2001
Office of Policy, Planning and Program Evaluation								
International Affairs and Energy Emergencies—NA								
Total operating	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Technical personnel	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Emergency Planning—NC								
Total operating	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.1
Technical personnel	0.2	0.7	0.3	0.1	0.1	0.1	0.1	0.1
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	0.2	0.7	0.3	0.1	0.1	0.1	0.1	0.1
Policy, Analysis, and System Studies—PE								
Total operating	1.4	1.0	1.2	1.1	1.1	1.1	1.1	1.1
Technical personnel	6.9	4.5	7.5	7.5	7.5	7.5	7.5	7.5
Other direct personnel	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	6.9	4.6	7.5	7.5	7.5	7.5	7.5	7.5
Total Office of Policy, Planning and Program Evaluation								
Total operating	1.7	1.2	1.4	1.2	1.2	1.2	1.2	1.2
Technical personnel	7.1	5.3	3.1	2.6	2.6	2.6	2.6	2.6
Other direct personnel	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	7.1	5.4	3.1	2.6	2.6	2.6	2.6	2.6
Office of the Associate Deputy Secretary for Field Management								
In-House Energy Management—WB								
Total operating	0.4	0.4	0.1	0.1	0.1	0.1	0.1	0.1
Construction	2.1	1.7	0.0	0.0	0.0	0.0	0.0	0.0
Total program	2.5	2.1	0.1	0.1	0.1	0.1	0.1	0.1
Technical personnel	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	2.1	3.8	1.6	0.3	0.3	0.3	0.3	0.3
Total direct personnel	2.1	9.8	1.6	0.3	0.3	0.3	0.3	0.3
Total Office of Assistant Deputy Secretary for Field Management								
Total operating	0.4	0.4	0.1	0.1	0.1	0.1	0.1	0.1
Construction	2.1	1.7	0.0	0.0	0.0	0.0	0.0	0.0
Total program	2.5	2.1	0.1	0.1	0.1	0.1	0.1	0.1
Technical personnel	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	2.1	3.8	1.6	0.3	0.3	0.3	0.3	0.3
Total direct personnel	2.1	9.8	1.6	0.3	0.3	0.3	0.3	0.3
Federal Energy Regulatory Commission								
Federal Energy Regulatory Commission—VR								
Total operating	2.2	0.6	1.0	0.0	0.0	0.0	0.0	0.0
Technical personnel	5.2	5.0	7.4	0.0	0.0	0.0	0.0	0.0
Other direct personnel	0.8	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Total direct personnel	6.0	5.1	7.5	0.0	0.0	0.0	0.0	0.0
Total Federal Energy Regulatory Commission								
Total operating	2.2	0.6	1.0	0.0	0.0	0.0	0.0	0.0
Technical personnel	5.2	5.0	7.4	0.0	0.0	0.0	0.0	0.0
Other direct personnel	0.8	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Total direct personnel	6.0	5.1	7.5	0.0	0.0	0.0	0.0	0.0

Table 8.5

(continued)

	1994	1995	1996	1997	1998	1999	2000	2001
Office of Economic Impact and Diversity								
Government Administration—Program Direction—WA								
Total operating	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Technical personnel	0.2	1.0	0.2	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	1.0	0.2	0.0	0.0	0.0	0.0	0.0
Total Office of Economic Impact and Diversity								
Total operating	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Technical personnel	0.2	1.0	0.2	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	1.0	0.2	0.0	0.0	0.0	0.0	0.0
DOE Funding from Energy Systems Central Organizations								
Uranium Enrichment and Decommissioning Fund—EU								
Total operating	9.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Technical personnel	26.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	5.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	29.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Environmental Restoration and Waste Management—Defense—EW								
Total operating	64.1	85.2	75.0	75.0	75.0	75.0	75.0	75.0
Capital equipment	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Construction	5.0	22.8	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction	0.0	0.0	5.0	5.0	0.0	0.0	0.0	0.0
Total program	71.6	110.5	82.5	82.5	77.5	77.5	77.5	77.5
Technical personnel	237.1	303.1	315.9	315.7	315.7	315.7	315.7	315.7
Other direct personnel	39.9	42.4	37.6	46.8	46.8	46.8	46.8	46.8
Total direct personnel	277.0	345.5	353.5	362.5	362.5	362.5	362.5	362.5
Environmental Restoration and Waste Management—Non-Defense—EX								
Total operating	86.2	68.4	65.0	65.0	65.0	65.0	65.0	65.0
Capital equipment	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Construction	7.5	22.4	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction	0.0	0.0	25.0	25.0	25.0	25.0	25.0	25.0
Total program	93.7	90.9	90.0	90.0	90.0	90.0	90.0	90.0
Technical personnel	221.4	295.1	302.6	308.1	308.1	308.1	308.1	308.1
Other direct personnel	57.0	79.7	83.1	79.8	79.8	79.8	79.8	79.8
Total direct personnel	278.4	374.8	385.7	387.9	387.9	387.9	387.9	387.9
Total DOE Funding from Energy Systems Central Organizations								
Total operating	159.8	153.6	140.0	140.0	140.0	140.0	140.0	140.0
Capital equipment	2.5	2.6	2.5	2.5	2.5	2.5	2.5	2.5
Construction	12.5	45.2	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction	0.0	0.0	30.0	30.0	25.0	25.0	25.0	25.0
Total program	174.8	201.4	172.5	172.5	167.5	167.5	167.5	167.5
Technical personnel	484.5	598.2	618.5	623.8	623.8	623.8	623.8	623.8
Other direct personnel	102.3	122.1	120.7	126.6	126.6	126.6	126.6	126.6
Total direct personnel	586.8	720.3	739.2	750.4	750.4	750.4	750.4	750.4

Table 8.5
(continued)

	1994	1995	1996	1997	1998	1999	2000	2001
Subtotal—DOE Programs								
Operating expense	471.0	475.0	461.8	472.1	472.1	472.1	472.1	472.1
Capital equipment	23.1	23.3	24.2	25.1	25.1	25.1	25.1	25.1
Construction	24.6	81.2	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction	0.0	0.0	43.5	42.8	33.9	27.2	25.0	25.0
Total program	518.7	579.5	529.5	540.0	531.1	524.4	522.2	522.2
Technical personnel	1474.9	1654.3	1691.0	1698.6	1698.6	1698.6	1698.6	1698.6
Other direct personnel	203.7	242.5	202.2	199.8	199.8	199.8	199.8	199.8
Total direct personnel	1678.6	1896.8	1893.2	1898.4	1898.4	1898.4	1898.4	1898.4
DOE Contractors and Operations Office								
Operating expense	20.8	18.3	16.6	17.5	17.5	17.5	17.5	17.5
Capital equipment	0.2	3.7	0.0	0.0	0.0	0.0	0.0	0.0
Total program	21.0	22.0	16.6	17.5	17.5	17.5	17.5	17.5
Technical personnel	63.5	59.9	44.5	23.8	23.8	23.8	23.8	23.8
Other direct personnel	11.0	12.3	19.9	15.3	15.3	15.3	15.3	15.3
Total direct personnel	74.5	72.2	64.4	39.1	39.1	39.1	39.1	39.1
Cooperative R&D Agreements								
Operating expense	0.6	0.7	1.3	1.2	1.2	1.2	1.2	1.2
Technical personnel	3.6	2.5	1.3	1.3	1.3	1.3	1.3	1.3
Other direct personnel	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	3.6	2.6	1.3	1.3	1.3	1.3	1.3	1.3
Total DOE Programs								
Operating expense	491.8	493.3	478.4	489.6	489.6	489.6	489.6	489.6
Capital equipment	23.3	27.0	24.2	25.1	25.1	25.1	25.1	25.1
Construction	24.6	81.2	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction	0.0	0.0	43.5	42.8	33.9	27.2	25.0	25.0
Total	539.7	601.5	546.1	557.5	548.6	541.9	539.7	539.7
Technical personnel	1538.4	1714.2	1735.5	1722.4	1722.4	1722.4	1722.4	1722.4
Other direct personnel	214.7	254.8	222.1	215.1	215.1	215.1	215.1	215.1
Total direct personnel	1753.1	1969.0	1957.6	1937.5	1937.5	1937.5	1937.5	1937.5
Work for others								
Nuclear Regulatory Commission								
Operating expense	19.4	16.2	15.0	15.0	15.0	15.0	15.0	15.0
Capital equipment	0.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Total	19.9	16.4	15.0	15.0	15.0	15.0	15.0	15.0
Technical personnel	80.9	82.3	78.3	76.3	76.3	76.3	76.3	76.3
Other direct personnel	4.5	4.4	4.3	3.0	3.0	3.0	3.0	3.0
Total direct personnel	85.4	86.7	82.6	79.3	79.3	79.3	79.3	79.3
Department of Defense								
Operating expense	22.2	25.5	22.4	24.4	24.4	24.4	24.4	24.4
Capital equipment	5.1	8.7	0.0	0.0	0.0	0.0	0.0	0.0
Total	27.3	34.2	22.4	24.4	24.4	24.4	24.4	24.4
Technical personnel	121.5	117.9	95.3	90.1	90.1	90.1	90.1	90.1
Other direct personnel	20.1	10.5	12.4	6.6	6.6	6.6	6.6	6.6
Total direct personnel	141.6	128.4	107.7	96.7	96.7	96.7	96.7	96.7

Table 8.5

(continued)

	1994	1995	1996	1997	1998	1999	2000	2001
National Aeronautics and Space Administration								
Operating expense	5.7	2.4	1.9	1.9	1.9	1.9	1.9	1.9
Technical personnel	12.9	7.6	7.2	6.4	6.4	6.4	6.4	6.4
Other direct personnel	0.3	0.6	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	13.2	8.2	7.2	6.4	6.4	6.4	6.4	6.4
Department of Health and Human Services								
Operating expense	3.5	2.2	4.6	4.8	4.8	4.8	4.8	4.8
Capital equipment	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	3.6	2.2	4.6	4.8	4.8	4.8	4.8	4.8
Technical personnel	15.8	15.9	24.6	23.1	23.1	23.1	23.1	23.1
Other direct personnel	0.1	0.1	0.6	0.5	0.5	0.5	0.5	0.5
Total direct personnel	15.9	16.0	25.2	23.6	23.6	23.6	23.6	23.6
Environmental Protection Agency								
Operating expense	1.1	2.2	0.0	0.0	0.0	0.0	0.0	0.0
Technical personnel	10.4	15.0	1.3	0.0	0.0	0.0	0.0	0.0
Other direct personnel	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	10.5	15.1	1.3	0.0	0.0	0.0	0.0	0.0
National Science Foundation								
Operating expense	0.1	0.0	0.5	0.5	0.5	0.5	0.5	0.5
Technical personnel	3.2	0.4	1.0	1.0	1.0	1.0	1.0	1.0
Other direct personnel	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	3.4	0.4	1.0	1.0	1.0	1.0	1.0	1.0
Federal Emergency Management Agency								
Operating expense	2.0	1.6	2.6	1.3	1.3	1.3	1.3	1.3
Capital equipment	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Total program	2.0	1.6	2.7	1.4	1.4	1.4	1.4	1.4
Technical personnel	4.6	3.3	11.8	8.7	8.7	8.7	8.7	8.7
Other direct personnel	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	4.6	3.9	11.8	8.7	8.7	8.7	8.7	8.7
Department of Transportation								
Operating expense	12.2	17.5	10.5	11.8	11.8	11.8	11.8	11.8
Capital equipment	0.2	0.3	0.4	0.3	0.3	0.3	0.3	0.3
Total program	12.4	17.8	10.9	12.1	12.1	12.1	12.1	12.1
Technical personnel	17.4	25.0	35.7	35.5	35.5	35.5	35.5	35.5
Other direct personnel	0.1	1.1	1.4	1.7	1.7	1.7	1.7	1.7
Total direct personnel	17.5	26.1	37.1	37.2	37.2	37.2	37.2	37.2
Other Federal agencies								
Total operating	4.8	(3.4)	3.1	2.3	2.3	2.3	2.3	2.3
Capital equipment	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total program	5.0	(3.4)	3.1	2.3	2.3	2.3	2.3	2.3
Technical personnel	10.9	13.5	16.8	25.5	25.5	25.5	25.5	25.5
Other direct personnel	0.3	0.9	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	11.2	14.4	16.8	25.5	25.5	25.5	25.5	25.5

Table 8.5

(continued)

	1994	1995	1996	1997	1998	1999	2000	2001
Electric Power Research Institute								
Operating expense	1.8	1.4	1.0	0.5	0.5	0.5	0.5	0.5
Technical personnel	7.6	6.2	4.1	1.6	1.6	1.6	1.6	1.6
Other direct personnel	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Total direct personnel	7.7	6.4	4.3	1.8	1.8	1.8	1.8	1.8
Other nonfederal agencies								
Total operating	4.8	6.5	1.5	0.9	0.9	0.9	0.9	0.9
Capital equipment	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Total	4.8	6.7	1.5	0.9	0.9	0.9	0.9	0.9
Technical personnel	18.9	21.4	11.1	6.8	6.8	6.8	6.8	6.8
Other direct personnel	0.8	2.4	1.4	0.6	0.6	0.6	0.6	0.6
Total direct personnel	19.7	23.8	12.5	7.4	7.4	7.4	7.4	7.4
Total Work for Others								
Total operating	77.6	72.1	63.1	63.4	63.4	63.4	63.4	63.4
Capital equipment	6.1	9.4	0.5	0.4	0.4	0.4	0.4	0.4
Total	83.7	81.5	63.6	63.8	63.8	63.8	63.8	63.8
Technical personnel	304.1	308.5	287.2	275.0	275.0	275.0	275.0	275.0
Other direct personnel	26.6	20.9	20.3	12.6	12.6	12.6	12.6	12.6
Total direct personnel	330.7	329.4	307.5	287.6	287.6	287.6	287.6	287.6
Total Program Resources								
Operating expense	569.4	565.4	541.5	553.0	553.0	553.0	553.0	553.0
Capital equipment	29.4	36.4	24.7	25.5	25.5	25.5	25.5	25.5
Construction	24.6	81.2	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction	0.0	0.0	43.5	42.8	33.9	27.2	25.0	25.0
Total	623.4	683.0	609.7	621.3	612.4	605.7	603.5	603.5
Technical personnel	1842.5	2022.7	2022.7	1997.4	1997.4	1997.4	1997.4	1997.4
Other direct personnel	241.3	275.7	242.4	227.7	227.7	227.7	227.7	227.7
Total direct personnel	2083.8	2298.4	2265.1	2225.1	2225.1	2225.1	2225.1	2225.1

Table 8.6
Estimated subcontracting and procurement by fiscal year
(\$ in millions—obligated)

	1994 ^a	1995	1996	1997
Universities	26.0	26.9	27.9	28.8
All others	179.0	185.3	191.7	198.5
Transfers to other DOE facilities	5.0	5.2	5.1	5.5
Total external subcontracts and procurements	210.0	217.4	224.7	232.8
^a Actual.				

Table 8.7
Estimated small and disadvantaged business procurement
by fiscal year
(\$ in millions—BA)

	1994	1995
Total small and disadvantaged business	88.8	91.9
Disadvantaged business	21.5	22.3
Women- and minority-owned business	15.1	15.6
Labor surplus (economically depressed area)	26.3	27.2

Appendix

Site and Facilities Data

ORNL occupies 3,115,808 gross square feet (GSF) of building space at the main site (Bethel Valley, Melton Valley, and the Copper Ridge area), 938,869 GSF of building space at the Oak Ridge Y-12 Plant, and 14,673 GSF of space at the Oak Ridge K-25 Site. ORNL also leases 89,524 GSF of space off site. Figures A.1–A.6 illustrate the current distribution, use, age, condition, and size of ORNL buildings. Figure A.7 shows the level of capital funding for nonenvironmental capital improvements at ORNL over the past several years. Figure A.8 shows anticipated/expected requirements for Multiprogram Energy Laboratory Facility Support (MEL-FS) line item construction projects from FY 1998 through FY 2001.

Table A.1 lists estimated facility replacement values. These estimates are based on active functions and do not include replacement of obsolete facilities or costs associated with decontamination and decommissioning (D&D) of existing facilities. Table A.2 lists ORNL's capital equipment investment. Table A.3 lists major construction projects for the planning period (excluding the MEL-FS projects shown in Fig. A.8). This list includes the Oak Ridge Spallation Neutron Source, the Center for Biological Sciences, and other facilities needed to support ORNL missions.

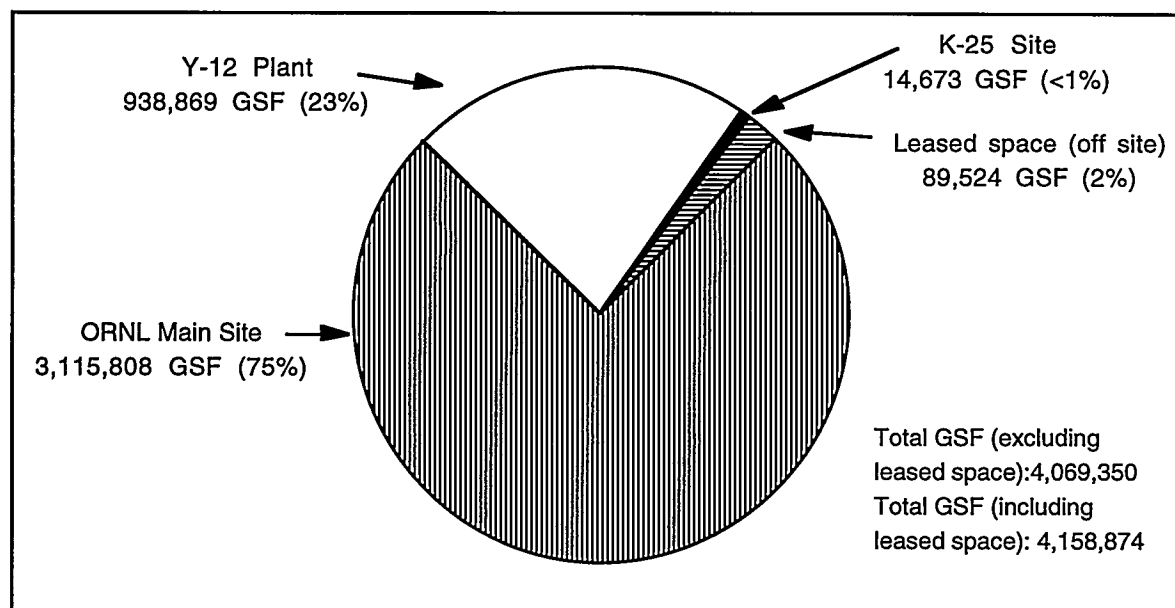


Figure A.1
ORNL space distribution—location and building area in gross square feet (GSF).

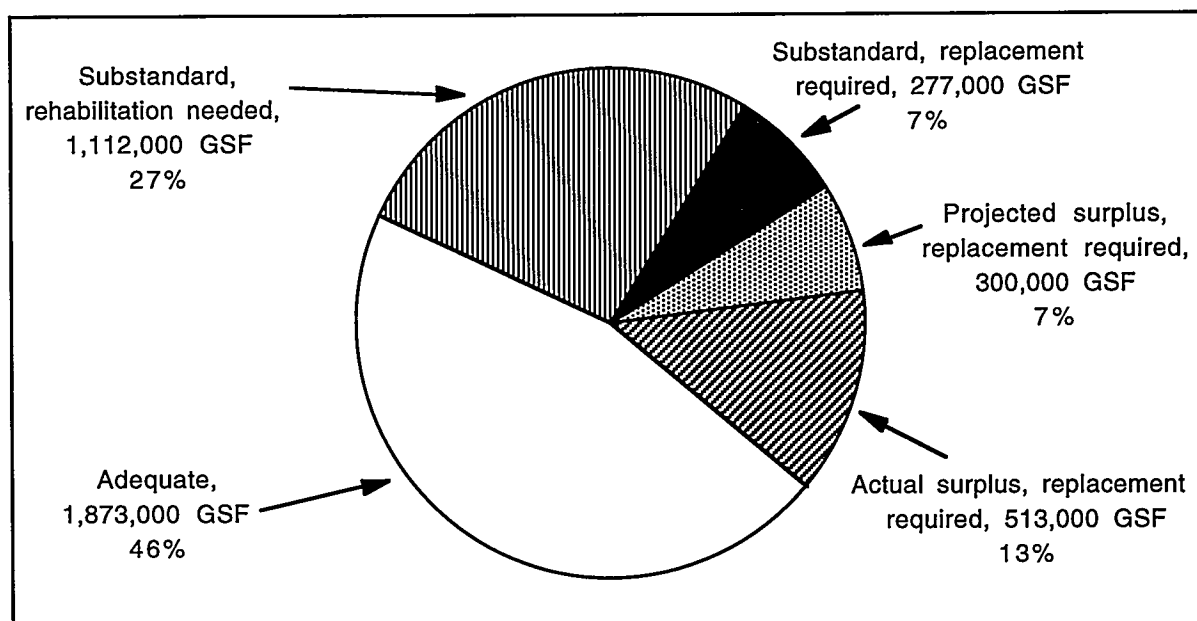


Figure A.2

Condition of ORNL space. In the actual surplus category, 348,000 GSF of the total 513,000 GSF is located at the Y-12 Plant.

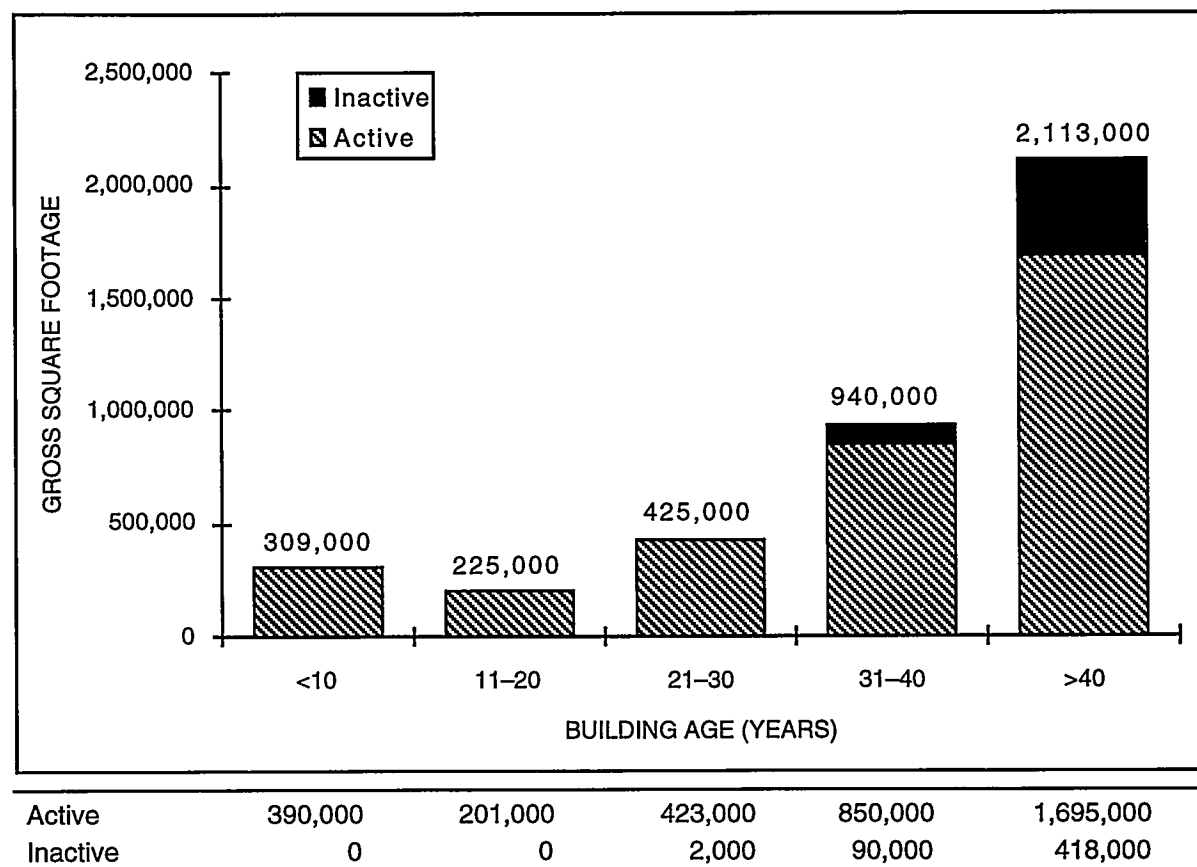


Figure A.3

Age of ORNL buildings. "Inactive" includes only actual surplus buildings. Of buildings over 40 years old, 348,000 GSF of the total 418,000 GSF of inactive space is located at the Y-12 Plant.

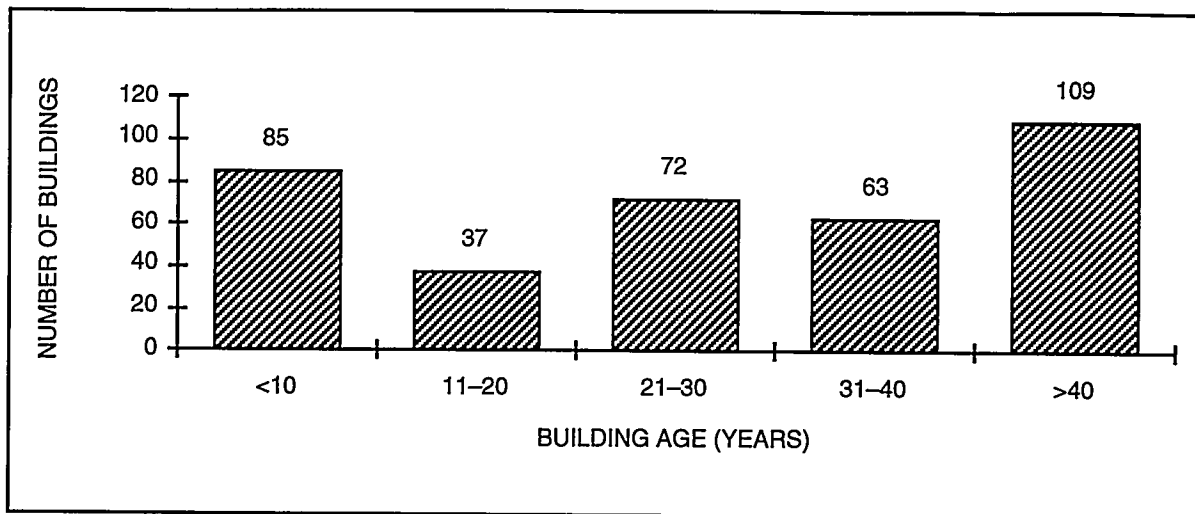


Figure A.4

Number of ORNL buildings, categorized by age. Of 366 buildings, 172 (47%) are over 30 years old.

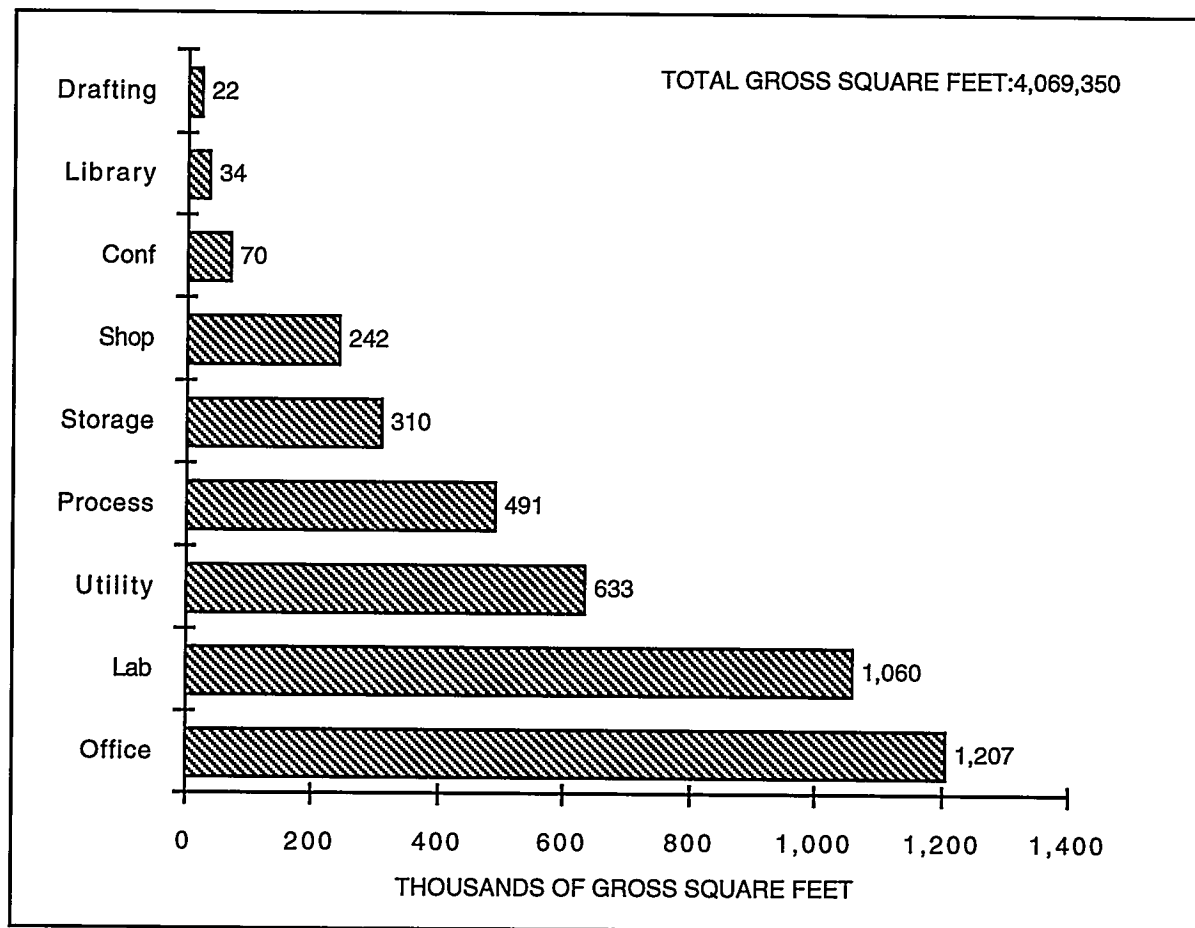


Figure A.5

Use of ORNL space by functional unit.

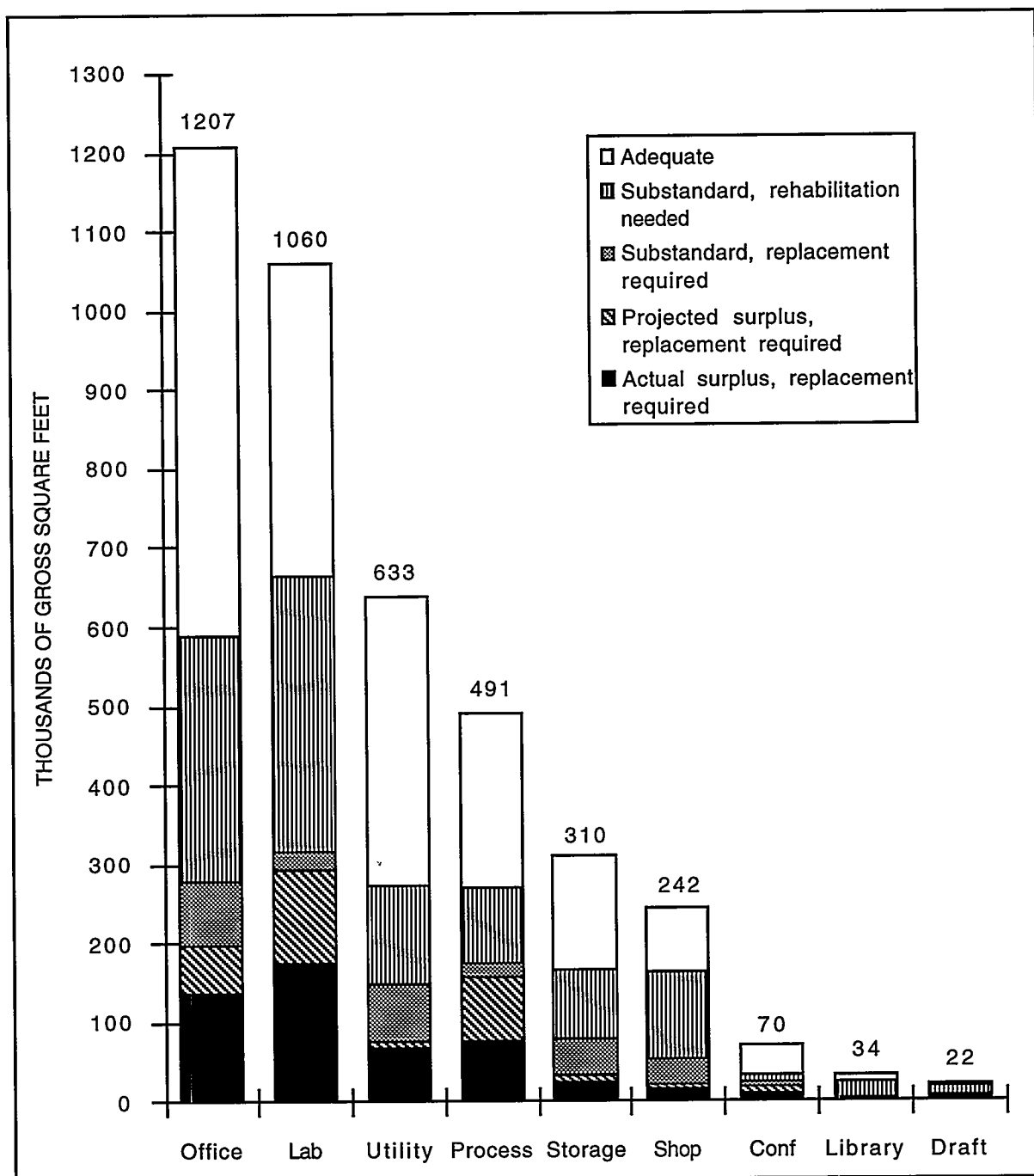


Figure A.6

Condition of ORNL space, categorized by functional unit.

	Office	Lab	Utility	Process	Storage	Shop	Conf	Library	Drafting
Active									
Adequate	618	396	364	222	145	80	36	7	5
Substandard									
Needs rehabilitation	310	346	126	94	85	109	10	22	10
Replacement required	80	25	72	16	48	31	4	1	0
Inactive (replacement required)									
Projected surplus	62	117	8	83	8	8	9	3	2
Actual surplus	137	176	68	76	24	15	11	0	6
Total	1207	1060	638	491	310	243	70	33	23

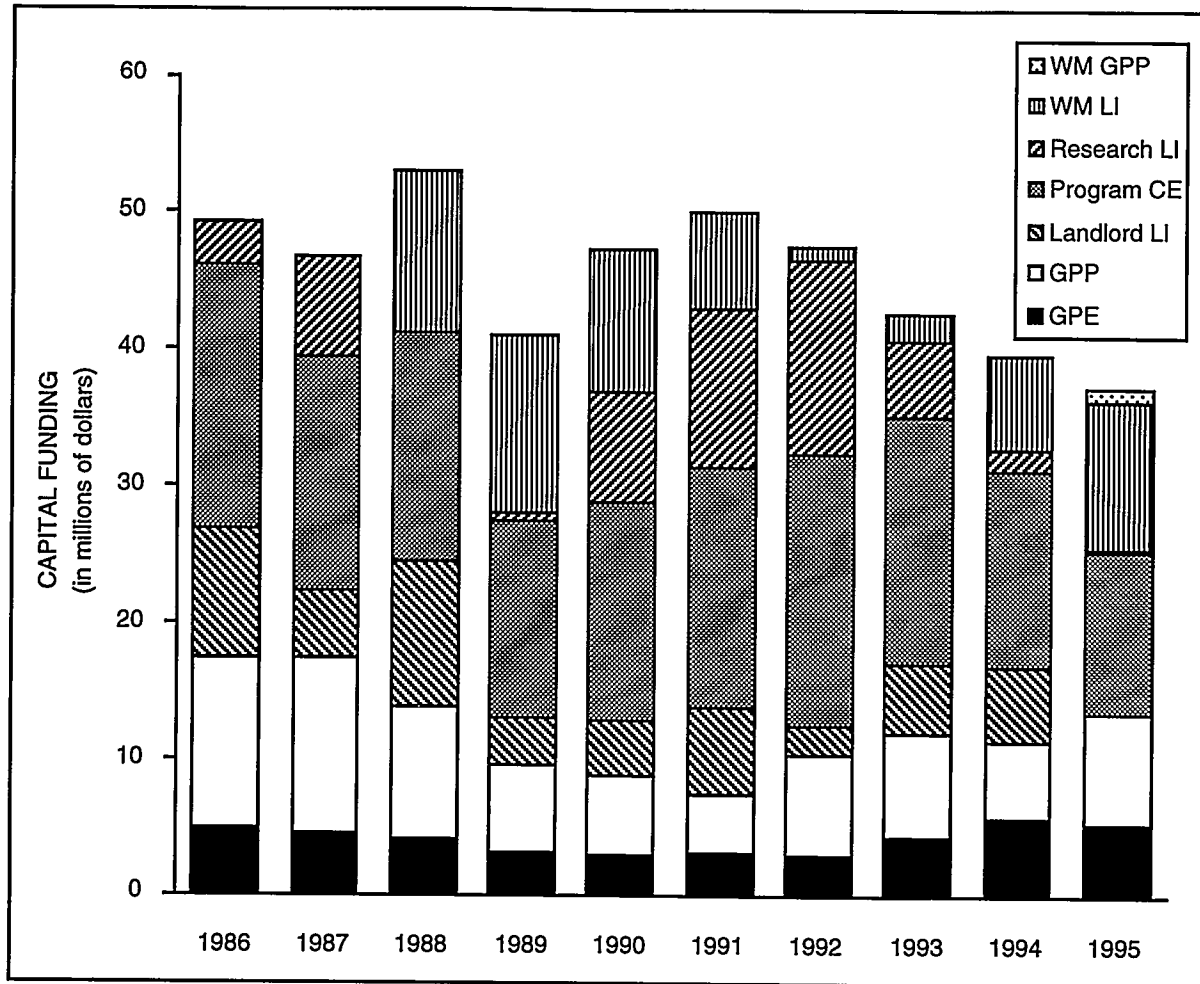
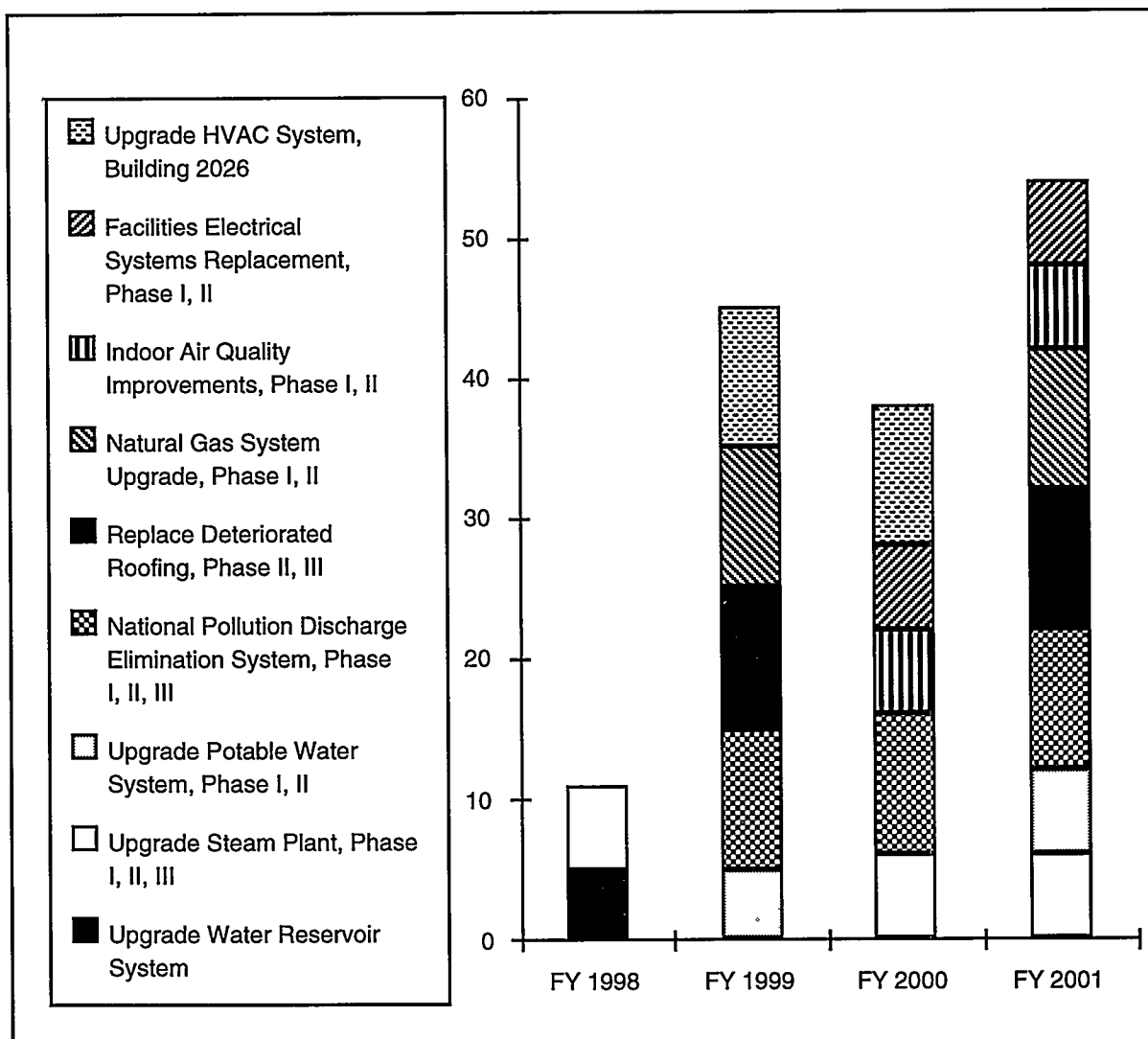


Figure A.7

Funding levels for nonenvironmental capital improvements at ORNL. GPE = general-purpose equipment. GPP = general plant project. LI = line item. CE = capital equipment. WM = waste management. Dollar amounts are by fiscal year (not adjusted for inflation).



Upgrade water reservoir system	5			
Upgrade steam plant, phases I, II, III	6		6	6
Upgrade potable water system, phases I, II		5		6
National Pollutant Discharge Elimination System, phases I, II, III		10	10	10
Replace deteriorated roofing, phases II, III		10		10
Upgrade natural gas system, phases I, II		10		10
Indoor air quality improvements, phases I, II			6	6
Facilities electrical systems replacement, phases I, II			6	6
Upgrade HVAC system, Building 2026		10	10	

Figure A.8

Anticipated/expected requirements, MEL-FS line item construction projects (costs in millions of dollars).

Table A.1
Estimated facilities replacement values^a

Facilities type	Replacement cost range ^b	
	Lower	Upper
Buildings and structures	818	1,156
Reactors	1,456	1,848
Process facilities	538	812
Accelerators	319	482
Utility systems	269	392
Roads, bridges, and parking	160	197
Security facilities	7	12
Automatic data-processing equipment	74	104
Motor vehicles	12	19
Heavy equipment	7	12
Other equipment and facilities	37	62
Subtotal, fixed-price construction	3,697	5,096
Engineering (35%)	1,294	1,784
Construction support services (20%)	739	1019
Operational readiness review (2.5%)	148	204
Construction manager (15%)	555	764
Subtotal	6,433	8,867
Contingency (40%)	2,573	3,547
Total	9,006	12,414

^aDOE estimates the replacement value of ORNL facilities at \$2.5 billion.

^bIn millions of FY 1995 dollars.

Table A.2
Capital equipment inventory

Functional unit	Description	Cost (\$ in thousands)
50	Heavy Mobile Equipment	3,626
51	Hospital & Medical	417
52	Lab Equipment	122,950
53	Motor Vehicles & Aircraft	9,573
54	Office Furniture	3,216
55	Process Equipment	25,036
57	Reactors and Accelerator	1,650
58	Security /Protection Equipment	308
59	Shop Equipment	19,403
60	Automated Data Processing	55,367
61	Portable Communications Electronic Equipment	449
79	Miscellaneous Equipment	3,775
	Total	245,770

Table A.3
Major construction projects^a
(\$ in millions)

	Funded construction		Budgeted construction	Proposed construction					TEC ^b
	1994	1995	1996	1997	1998	1999	2000	2001	
Research program line-item projects ^c									
Oak Ridge Spallation Neutron Source				24.4	40.3	179.7	227.6	192.5	852.6
Center for Biological Sciences					10.0	15.0			25.0
Advanced Materials Characterization Laboratory							9.0	9.0	27.0
Waste management projects									
Bethel Valley LLLW-CAT ^d system upgrade (WBS 3.37)	6.5	17.0	4.0	2.7					65.0
Upgrade process waste treatment system	9.6								9.6
Melton Valley LLLW-CAT system upgrade (WBS 3.45)	11.5	9.1							41.0
Upgrade sanitary sewer system	7.0	4.0	0.0	1.2	2.0				16.0
Bethel Valley FFA upgrades	3.6	7.0	0.3	1.1	0.0	5.0	3.6		22.1
MVST capacity increase	9.4	21.4	11.0	6.3	1.3				49.4
TRU Packaging Facility					3.0	25.0	75.0	75.0	350.0

^aConstruction data as of December 1995.

^bTotal estimated cost.

^cDoes not include accelerator and reactor improvements and modifications projects.

^dLLLW-CAT = low-level liquid waste collection and transfer.

^eMVST = Melton Valley Storage Tanks.

User Facility Data

Ten designated user facilities were operated in FY 1994, including the Oak Ridge Centers for Manufacturing Technology at the Oak Ridge Y-12 Plant. (Operation of the Holifield Radioactive Ion Beam Facility as a user facility is expected to commence in FY 1996.) Statistics for use in FY 1994 are shown in Table A.4. In FY 1994, 829 scientists representing 256 institutions conducted experiments at ORNL user facilities; 33% were university scientists. Growth in the industrial user population continued, with 131 experimenters from 74 companies in FY 1994, compared with 102 experimenters from 62 companies in FY 1993.

Table A.4
Experimenters at ORNL's designated user research facilities in FY 1994

	U.S. government laboratory ^a			University			Industry			International			Total	
	Exp. ^b	Org. ^c	% of use	Exp.	Org.	% of use	Exp.	Org.	% of use	Exp.	Org.	% of use	Exp.	User days
Holifield Radioactive Ion Beam Facility ^d	0	0	0	0	0	0	0	0	0	0	0	0	0	0
National Environmental Research Park ^e	97	7	51.2	42	12	27.4	24	4	19.2	4	2	2.2	167	25 6,064
High Temperature Materials Laboratory	106	3	51.6	72	32	15.2	63	33	33.2	0	0	0	241	68 14,204
Surface Modification and Characterization Research Center	31	5	58.6	44	20	33.3	7	6	2.8	11	8	5.3	93	39 2,281
Shared Research Equipment Program	38	1	82.2	25	15	6.7	1	1	0.1	4	4	11.0	68	21 2,139
Neutron Scattering Research Facilities ^f	47	6	59.3	55	23	18.3	24	21	8.7	30	18	13.7	156	68 6,772
EN Tandem Van de Graaff	9	2	36.2	21	5	63.8	0	0	0	0	0	0	30	7 1,877
Oak Ridge Electron Linear Accelerator	9	2	60.2	1	1	9.1	2	1	18.1	3	2	12.6	15	6 1,709
Bioprocessing Research Facility	10	1	75.1	4	4	13.9	2	1	11.0	0	0	0	16	6 346
Buildings Technology Center	0	0	0	1	1	50.0	0	0	0	1	1	50.0	2	2 400
Oak Ridge Centers for Manufacturing Technology	20	1	50.0	13	6	42.6	8	7	7.4	0	0	0	41	14 378
Total	367	28	44.4	278	119	33.5	131	74	15.8	53	35	6.3	829	256 36,170

^aIncludes 287 ORNL users (34.7% of use).

^bExp. = number of experimenters.

^cOrg. = number of organizations.

^dThe Holifield Radioactive Ion Beam Facility did not operate as a user facility during FY 1994. User operation will be resumed in FY 1996.

^eNumbers do not include over 25,000 individuals who participated in the Ecological and Physical Sciences Study Center and the High School Honors Program for a total of 10,434 user hours in FY 1994.

^fRedesignated the High Flux Isotope Reactor in 1995.

Science and Mathematics Education Data

ORNL provides educational opportunities to students and teachers at all levels, from preschool through postgraduate education. Statistics for use of ORNL's programs for the last two years for which complete data are available are presented in Table A.5.

Table A.5
Participation in science and math education programs

	FY 1993			FY 1994		
	Total	Minor- ities	Women	Total	Minor- ities	Women
Precollege student programs						
Adventures in Math/Science	191	100	95	100	54	47
Adventures in Supercomputing	296	30	134	528	45	241
ARC Honors Academy	35	3	17	33	2	18
DOE Honors Workshop	59	12	41	57	11	38
Clinch River Environmental Studies Organization	20	1	12	22	1	13
NAACP Scholars	—	—	—	17	17	10
Oak Ridge Educational Network	—	—	—	800	<i>a</i>	<i>a</i>
Project SEED/Hispanic SEED	18	12	13	15	10	10
Regional Science Bowls	295	35	46	270	30	65
Saturday Academy of Computing and Mathematics	45	2	21	28	2	13
Special Honors Study	8	1	1	2	0	1
Spectacles Camp, Wesleyan College	68	10	68	22	3	22
Ecological and Physical Sciences Study Center	20,897	1,960	10,400	23,734	2,100	16,800
Summer Science Experience	77	7	35	46	4	20
Women in Science and Tech- nology Conference	110	10	110	100	12	100
Junior Science/Humanities	135	10	69	129	10	66
Special Programs	425	105	208	450	102	220
Total	22,679	2,298	11,270	26,353	2,403	17,684

Table A.5

(continued)

	FY 1993			FY 1994		
	Total	Minor-ities	Women	Total	Minor-ities	Women
Precollege teacher programs						
Academy for Math/Science	82	9	55	80	7	53
Administrators Workshop	47	4	20	30	2	17
Adventures in Supercomputing	25	2	17	37	3	25
ARC Honors Academy	14	0	7	14	0	6
DOE Honors Workshop	5	1	3	4	1	2
DOE Teacher Research Associates	47	10	18	42	8	20
DOE Lyndhurst Fellows	12	0	8	12	0	4
Elementary Leadership Institute (NSF)	25	4	22	24	4	22
Hands-On Science Workshops	45	3	41	22	2	18
Project SMART	75	0	68	90	2	73
Science Enrichment	54	19	44	10	2	7
Saturday Academy of Computing and Mathematics	12	0	6	6	0	4
Teacher In-Service Training	362	334	229	354	40	221
Tri-State Educational Consortium	—	—	—	18	0	12
Total	805	386	538	743	71	484
Undergraduate programs						
Alliance for Minority Participation	—	—	—	6	4	6
Buildings Technology Internships	—	—	—	3	3	2
Cooperative Education	61	17	19	67	22	23
Customized Internships (HBCU)	2	2	2	2	2	2
DOE Science Semester (SERS)	72	10	37	77	11	29
DOE Summer Practicums	5	2	2	0	0	0
EMCOM	18	16	11	22	22	15
Graduate School Fair	—	—	—	325	60	180
GLCA/ACM Science Semester	16	0	6	25	8	7
Health/Environment (HBCU)	10	10	4	5	5	1
Nuclear Energy (HBCU)	4	4	3	6	6	3
Nuclear Regulatory (HBCU)	—	—	—	12	12	2
Professional Internship Program	64	5	21	72	11	28
SERS Summer Program	30	2	17	35	5	13
Science and Technology Alliance	5	5	0	13	12	5
Service Academies Research	0	0	0	0	0	0
Student Research Participation	30	3	13	25	2	9
Summer Technical Internship	106	32	47	44	8	19
Technology Internship Program	33	3	11	42	3	19
University of Puerto Rico	7	7	4	2	2	0
Women in Science Conference	192	19	187	200	25	198
Total	655	137	384	983	223	561

Table A.5

(continued)

	FY 1993			FY 1994		
	Total	Minor- ities	Women	Total	Minor- ities	Women
Graduate programs						
DOE Fellowship Practicums	4	0	0	5	0	1
Graduate Education for Minorities (GEMS)	5	5	1	3	3	1
Graduate Student Research	25	2	8	36	3	7
High Temperature Materials Fellowships	2	0	0	4	0	0
Laboratory Graduate Research	6	0	2	9	0	1
Law Internship Program	12	0	6	7	1	3
Materials Research (AIC)	4	2	2	2	2	0
Nuclear Energy Training	1	1	0	0	0	0
Professional Internship Program	27	3	13	48	4	15
Research Travel Contracts	13	0	1	10	0	5
Service Academies Research	0	0	0	0	0	0
Total	99	13	33	124	13	33
Postgraduate programs						
DOE Postdoctoral Programs						
Distinguished Postdoctoral	—	—	—	2	0	0
Fusion Energy	3	0	0	1	0	0
Global Change	3	0	0	4	0	0
Hollaender	7	0	2	6	0	2
Human Genome	1	0	0	2	0	0
ORNL Postdoctoral Research	136	3	22	193	5	31
Postgraduate Research Training Program	35	2	8	37	2	14
Wigner Postdoctoral Fellows	2	1	2	5	1	1
Total	187	6	34	250	8	48
Faculty programs						
Environmental Management (EMCOM)	7	6	2	1	1	0
Faculty Research Participation	44	9	2	40	9	12
Great Lakes/Midwest Colleges	2	0	1	3	0	1
HBCU Faculty Research	7	7	1	14	14	2
Minority Institution Research Travel	10	10	3	8	8	1
Research Travel	75	34	18	36	8	2
Science and Technology Alliance	6	3	1	7	3	2
Total	151	69	28	109	43	20

^aNot determined.

Human Resources Data

Tables A.6 and A.7 present statistics on the number of minority staff members at ORNL in 1989 and 1994. Table A.8 contains information on the composition of ORNL staff.

Table A.6
Equal employment opportunity statistics for 1989

Occupational code	Total (%) ^a		Minority total (%)		White (%)		Black (%)		Hispanic (%)		Native American (%)		Asian/Pacific Islander (%)	
	M ^b	F ^c	M	F	M	F	M	F	M	F	M	F	M	F
Officials and managers ^d	538 (92.0)	47 (8.0)	25 (4.3)	2 (0.3)	513 (87.7)	45 (7.7)	21 (3.6)	1 (0.2)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	4 (0.7)	1 (0.2)
Professional staff	1930 (80.4)	470 (19.6)	142 (5.9)	45 (1.9)	1788 (74.5)	425 (17.7)	43 (1.8)	27 (1.1)	17 (0.9)	1 (0.04)	2 (0.08)	1 (0.04)	80 (3.3)	16 (0.7)
Technicians	443 (69.9)	191 (30.1)	39 (6.2)	21 (3.3)	404 (63.7)	170 (26.8)	31 (4.9)	19 (3.0)	7 (1.1)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.2)	2 (0.3)
All other	923 (50.8)	893 (49.2)	137 (7.5)	128 (7.0)	786 (43.3)	765 (42.1)	131 (7.2)	116 (6.4)	2 (0.1)	6 (0.3)	2 (0.1)	2 (0.1)	2 (0.1)	4 (0.2)
Total	3834 (70.5)	1601 (29.5)	343 (6.3)	196 (3.6)	3491 (64.2)	1405 (25.9)	226 (4.1)	163 (3.0)	26 (0.5)	7 (0.1)	4 (0.07)	3 (0.06)	87 (1.6)	23 (0.4)

^aPercentage of total number of employees in occupational category.

^bM = male.

^cF = female.

^dAs defined on Standard Form 100 (EEO-1), as required by 41 CFR 60-1.7(a).

Table A.7
Equal employment opportunity statistics for 1994

Occupational code	Total (%) ^a		Minority total (%)		White (%)		Black (%)		Hispanic (%)		Native American (%)		Asian/Pacific Islander (%)	
	M ^b	F ^c	M	F	M	F	M	F	M	F	M	F	M	F
Officials and managers ^d	361 (90.7)	37 (9.3)	24 (6.0)	3 (0.8)	337 (84.6)	34 (8.5)	20 (5.0)	2 (0.5)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	4 (1.0)	1 (0.3)
Professional staff														
Scientists and engi- neers	1272 (86.4)	199 (13.5)	129 (8.8)	24 (1.6)	1143 (77.7)	175 (11.9)	30 (2.0)	11 (0.7)	18 (1.2)	3 (0.2)	1 (0.06)	1 (0.06)	80 (5.4)	9 (0.6)
Computing and adminis- trative	308 (58.4)	219 (41.5)	30 (5.7)	25 (4.7)	278 (52.8)	194 (36.8)	18 (3.4)	16 (3.0)	7 (1.3)	0 (0.0)	0 (0.0)	0 (0.0)	5 (0.9)	7 (1.3)
Technicians	324 (70.0)	139 (30.0)	22 (4.8)	17 (3.7)	302 (65.2)	122 (26.3)	17 (3.7)	13 (2.8)	5 (1.0)	0 (0.0)	0 (0.0)	1 (0.2)	0 (0.0)	3 (0.6)
All other	741 (51.3)	702 (48.6)	87 (6.0)	96 (6.7)	654 (42.0)	606 (42.0)	84 (5.8)	86 (6.4)	0 (0.0)	6 (0.4)	0 (0.0)	1 (0.06)	3 (0.2)	3 (0.2)
Total	3006 (69.9)	1296 (30.1)	292 (6.8)	165 (3.8)	2714 (63.0)	1131 (26.2)	169 (3.0)	128 (3.0)	30 (0.7)	8 (0.2)	1 (0.02)	3 (0.06)	92 (2.1)	23 (0.5)

^aPercentage of total number of employees in occupational category.

^bM = male.

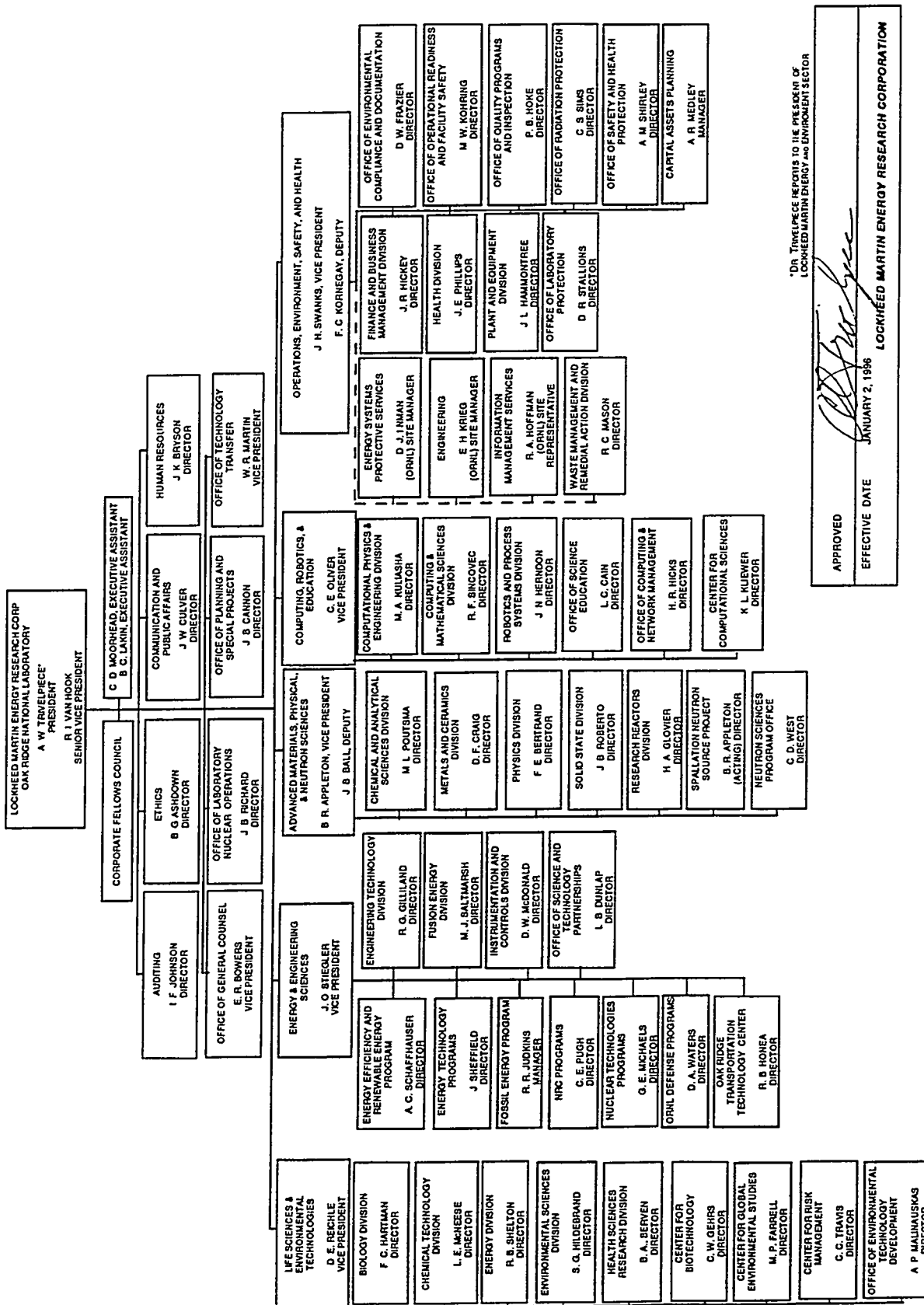
^cF = female.

^dAs defined on Standard Form 100 (EEO-1), as required by 41 CFR 60-1.7(a).

Table A.8
ORNL staff composition (as of January 1, 1995)^a

	Ph.D.	M.S.	B.S./B.A.	A.S.	Non- degreed	Total
Professional staff						
Scientists	464	169	131	6	25	795
Engineers	286	263	284	16	74	922
Management/administrative	119	114	140	5	57	435
Other	30	96	112	16	145	400
Total professional staff	899	642	667	43	301	2552
Support staff						
Technicians	0	8	86	121	275	490
Union employees (includes crafts, laborers, etc.)	0	1	11	28	940	980
Administrative/clerical	0	5	69	64	633	771
Other (supervisors of union employees)	0	1	7	9	75	92
Total support staff	0	15	173	222	1923	2333
Total ORNL staff	899	657	840	265	2224	4885

^aIncludes full-time regular employees.



Abbreviations

AA	affirmative action
AART	Alliance for the Advancement of Robotics Technology
AEOD	NRC Office for Analysis and Evaluation of Operational Data
AEP	Division of Advanced Energy Projects
AFCESA	Air Force Civil Engineering Support Agency
AHAM	Association of Home Appliance Manufacturers
AIC	Advanced Industrial Concepts
AID	U.S. Agency for International Development
AIS	Adventures in Supercomputing
ALWR	advanced light-water reactor
AMC	Air Mobility Command
AMCL	Advanced Materials Characterization Laboratory
AMS	Applied Mathematical Sciences
AMTEX	American Textile Partnership
ANS	Advanced Neutron Source
appm	atomic parts per million
ARL	Army Research Laboratory
ARM	Atmospheric Radiation Measurement
ARPA	Advanced Research Projects Agency
ASDEX-U	Axially Symmetric Divertor Experiment Upgrade
ASP	Accident Sequence Precursor
ATM	asynchronous transfer mode
ATS	Advanced Turbine System
ATSDR	Agency for Toxic Substances and Disease Registry
B&W	Babcock and Wilcox
BA	budget authority
BES	Basic Energy Sciences
BESAC	Basic Energy Sciences Advisory Committee
BFDP	Biofuels Feedstock Development Program
BNL	Brookhaven National Laboratory
BO	budget outlay
BRDC	Bioprocessing Research and Development Center
BTC	Buildings Technology Center
BWR	boiling-water reactor
C-CAP	Coastal Change Analysis Program
CADDET	Center for Analysis and Dissemination of Demonstrated Energy Technologies
CANDU	Canadian deuterium-uranium reactor
CBS	Center for Biological Sciences
CCII	Computational Center for Industrial Innovation
CCS	Center for Computational Sciences
CCTP	Clean Coal Technology Project
CDIAC	Carbon Dioxide Information Analysis Center
cDNA	complementary deoxyribonucleic acid

CDNSWC	Carderock Division, Naval Surface Warfare Center
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERN	European Laboratory for Particle Physics (formerly Conseil Européen pour la Recherche Nucléaire)
CESAR	Center for Engineering Systems Advanced Research
CET	Center for Environmental Technology
CFADC	Controlled Fusion Atomic Data Center
CFC	chlorofluorocarbon
CFCC	continuous fiber ceramic composite
CFR	Code of Federal Regulations
CGES	Center for Global Environmental Studies
CHAMMP	Computer Hardware, Advanced Mathematics, and Model Physics
CHS	Compact Helical System
CMC-CAT	Complex Materials Consortium Collaborative Access Team
CRADA	cooperative research and development agreement
CSCP	Center for Separations and Chemical Processing
CURE	Chemical Unit Record Estimates
D&D	decontamination and decommissioning
D-T	deuterium-tritium
DAAC	Distributed Active Archive Center
DAE	differential-algebraic equation
DAMA	demand activated manufacturing architecture
DMS	Division of Materials Science
DNA	deoxyribonucleic acid
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOE-DP	U.S. Department of Energy, Office of Defense Programs
DOE-EE	U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy
DOE-EH	U.S. Department of Energy, Office of Environment, Safety, and Health
DOE-EM	U.S. Department of Energy, Office of Environmental Management
DOE-ER	U.S. Department of Energy, Office of Energy Research
DOE-FE	U.S. Department of Energy, Office of Fossil Energy
DOE-HQ	U.S. Department of Energy, Headquarters
DOE-ID	U.S. Department of Energy, Idaho Operations Office
DOE-MD	U.S. Department of Energy, Office of Fissile Materials Disposition
DOE-NE	U.S. Department of Energy, Office of Nuclear Energy, Science and Technology
DOE-OFE	U.S. Department of Energy, Office of Fusion Energy
DOE-ORO	U.S. Department of Energy, Oak Ridge Operations Office
DOE-PO	U.S. Department of Energy, Assistant Secretary for Policy, Planning, and Program Evaluation
DOE-RW	U.S. Department of Energy, Office of Civilian Radioactive Waste Management
DRS	Daresbury Recoil Separator
DSM	demand-side management
EAS	environmental analysis support
ECR	electron cyclotron resonance
EEO	equal employment opportunity
EEO/AA	equal employment opportunity/affirmative action
EES	Evaluation of Early Systems
EGF	epidermal growth factor
EIA	Energy Information Administration
EMF	electric and magnetic fields
EMIC	Environmental Mutagen Information Center
ENEA	National Committee for Research and Development of Nuclear and Alternative Energy (Italy)

Energy Systems	Lockheed Martin (formerly Martin Marietta) Energy Systems, Inc.
EOSDIS	Earth Observing System Data and Information System
EPA	U.S. Environmental Protection Agency
EPACT	Environmental Policy Act of 1992
EPRI	Electric Power Research Institute
ER-LTA	Energy Research Laboratory Technology Applications Program
ERDMP	Environmental Restoration Data Management Program
ES&H	environmental, safety, and health
FDA	Food and Drug Administration
FDDI	fiber distributed data interface
FEMA	Federal Emergency Management Agency
FERC	Federal Energy Regulatory Commission
FFA	Federal Facilities Agreement
FICA	Facility Interface Capability Assessment
FT	Fourier transform
FTE	full-time equivalent
ftp	File Transfer Protocol
FUSRAP	Formerly Utilized Sites Remedial Action Project
FWCD	fast wave current drive
FWP	Field Work Proposal
FY	fiscal year
GAX	generator-absorber-heat exchanger
GCM	general circulation model
GEM	genetically engineering microorganism
GIS	geographic information system
GMODS	glass material oxidation and dissolution system
GPE	general-purpose equipment
GPP	general plant project
GRAIL	Gene Recognition and Analysis Internet Link
GREENTIE	Greenhouse Gas Technology Information Exchange
GSF	gross square feet
GT-MHR	gas turbine-modular helium reactor
GUI	graphical user interface
HBCU	historically black college or university
HCFC	hydrochlorofluorocarbon
HEU	highly enriched uranium
HFIR	High Flux Isotope Reactor
HGMIS	Human Genome Management Information System
HPCC	High Performance Computing and Communications
HPSS	High Performance Storage System
HRIBF	Holifield Radioactive Ion Beam Facility
HSRD	Health Sciences Research Division
HSSI	NRC Heavy-Section Steel Irradiation Program
HSST	NRC Heavy-Section Steel Technology Program
HTML	High Temperature Materials Laboratory
I&C	instrumentation and controls
I/O	input/output
ICRF	ion cyclotron range of frequencies
IDB	Integrated Data Base
IEA	International Energy Agency
IEF	Isotope Enrichment Facility
IFDP	Isotope Facilities Deactivation Project
IFMIF	International Fusion Materials Irradiation Facility
IFP	Integrated Facilities Plan

INS	Institute for Neutron Sciences
IRM	information resource management
ITER	International Thermonuclear Experimental Reactor
JCT	Joint Central Team
JET	Joint European Torus
LANL	Los Alamos National Laboratory
LBNL	Lawrence Berkeley National Laboratory
LDRD	Laboratory Directed Research and Development
LLLW	low-level liquid waste
LLNL	Lawrence Livermore National Laboratory
LOF	liquid-overfeed
LWR	light-water reactor
MAB	monoclonal antibody
MEL-FS	Multiprogram Energy Laboratories Facilities Support
METC	Morgantown Energy Technology Center
MHATT-CAT	Howard University–University of Michigan–AT&T Bell Laboratories Collaborative Access Team
MIME	multipurpose Internet mail extension
MIT	Massachusetts Institute of Technology
MOCVD	metallic organic chemical vapor deposition
MOX	mixed-oxide
MPLUS	Metals Processing Laboratory User Center
MPP	massively parallel processing
MRDL	Metrology Research and Development Laboratory
mRNA	messenger ribonucleic acid
NASA	National Aeronautics and Space Administration
NCI	National Cancer Institute
NEAT	National Energy Audit
NEPA	National Environmental Policy Act
NERSC	National Energy Research Supercomputer Center
NICHHD	National Institute for Child Health and Human Development
NIEHS	National Institute for Environmental Health Sciences
NIH	National Institutes of Health
NII	National Information Infrastructure
NMR	nuclear magnetic resonance
NMSS	NRC Office of Nuclear Material Safety and Safeguards
NOAA	National Oceanic and Atmospheric Administration
NRC	Nuclear Regulatory Commission
NSF	National Science Foundation
OCRWM	DOE Office of Civilian Radioactive Waste Management
OHER	DOE Office of Health and Environmental Research
OIT	Office of Industrial Technologies
ORCHID	Oak Ridge Center for Healthcare Industry Development
ORCMT	Oak Ridge Centers for Manufacturing Technology
OREIS	Oak Ridge Environmental Information System
ORELA	Oak Ridge Electron Linear Accelerator
ORISE	Oak Ridge Institute for Science and Education
ORNL	Oak Ridge National Laboratory
ORSNS	Oak Ridge Spallation Neutron Source
ORSOAR	ORNL-ORISE Synchrotron Organization for Advanced Research
ORTAN	Oak Ridge Transportation Technology Center
OSE	Office of Science Education
OSH	occupational safety and health
OSHA	Occupational Safety and Health Administration

OSTP	Office of Science and Technology Policy
PC	personal computer
PCB	polychlorinated biphenyl
PEIS	programmatic environmental impact statement
PER	Program for Ecosystem Research
PETC	Pittsburgh Energy Technology Center
PHENIX	Photon Electron New Heavy Ion Experiment
PICS	Partnership in Computational Science
PMT	Performance Measurement Team
PNGV	Partnership for a New Generation of Vehicles
PPPL	Princeton Plasma Physics Laboratory
PRK	phosphoribulokinase
PVM	Parallel Virtual Machine
QA	quality assurance
QMR	quasiminimal residual
R&D	research and development
RAP	remedial action project
RAPIC	Remedial Action Program Information Center
RCRA	Resource Conservation and Recovery Act
RDDT&E	research, development, demonstration, testing, and evaluation
RDF	Radiochemical Development Facility
REDC	Radiochemical Engineering Development Center
RELAP	Reactor Loss of Coolant Analysis Program
RES	NRC Office of Nuclear Regulatory Research
rf	radio frequency
RFTF	Radio Frequency Test Facility
RHIC	Relativistic Heavy Ion Collider
RIB	radioactive ion beam
RIED	radiation-induced electrical degradation
RMS	recoil mass spectrometer
RNA	ribonucleic acid
RPSD	Robotics and Process Systems Division
RRD	Research Reactors Division
RSIC	Radiation Shielding Information Center
RTG	radioisotope thermoelectric generator
Rubisco	ribulose biphosphate carboxylase/oxygenase
S&M	surveillance and maintenance
SARPIS	Space Allocation and Real Property Inventory System
SAS	NRC Surveillance Data Base, Analysis, and Standardization program
SCALE	Standardized Computer Analysis for Licensing Evaluation
SCDAP	Severe Core Damage Analysis Program
SCSS	Sequence Coding and Search System
SEED	Summer Educational Experience for the Disadvantaged
SERDP	Strategic Environmental Research and Development Program
SERS	Science and Engineering Research Semester
SFMP	Surplus Facilities Management Program
SGML	Standard Generalized Markup Language
SHaRE	Shared Research Equipment
SIAC	specialized information analysis center
SMACRC	Surface Modification and Characterization Research Center
SMART	Science/Math Action for Revitalized Teaching
SNL	Sandia National Laboratories
SRS	Savannah River Site
SSP	Subsurface Science Program

ST	Spherical Tokamak
START	Small Tight-Aspect-Ratio Tokamak
STM	scanning tunneling microscopy
SWSA	Solid Waste Storage Area
TACOM	Tank Automotive Command
Td	thioredoxin
TEAM	Technologies Enabling Agile Manufacturing
TEXTOR	Tokamak Experiment for Technology Oriented Research
TFTR	Tokamak Fusion Test Reactor
TGF- β	transforming growth factor-beta
TIRC	Toxicology Information Response Center
TPX	Tokamak Physics Experiment
TSCA	Toxic Substances Control Act
TSU	Tennessee State University
TTI	Technology Transfer Initiative
TVA	Tennessee Valley Authority
UMTRAP	Uranium Mill Tailings Remedial Action Project
UNI-CAT	University-National Laboratory-Industry Collaborative Access Team
USDA	U.S. Department of Agriculture
USGCRP	U.S. Global Change Research Program
USTRANSCOM	U.S. Army Transportation Command
UT	The University of Tennessee
UTK	The University of Tennessee at Knoxville
UV-B	ultraviolet B
VOC	volatile organic compound
VP	virtual prototyping
W7AS	Wendelstein VII-AS
WAG	Waste Area Grouping
WDC-A	World Data Center-A for Atmospheric Trace Gases
WFO	work for others
WWW	World Wide Web