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OAK RIDGE NATIONAL LABORATORY

LOCKHEED MARTIN

Oak Ridge National Laboratory Institutional Plan

FY 1999–FY 2003

MANAGED AND OPERATED BY
LOCKHEED MARTIN ENERGY RESEARCH CORPORATION
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

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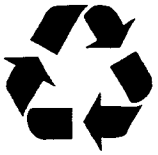

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Oak Ridge National Laboratory Institutional Plan

FY 1999–FY 2003

December 1998

Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831-6285
managed by
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for the
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Contents

1. Laboratory Director's Statement

In January 1996, when the management and operation (M&O) contract for the Oak Ridge National Laboratory (ORNL) was awarded to Lockheed Martin Energy Research Corporation, we were presented with the opportunity to develop and implement a management structure tailored to the Laboratory's needs and functions. In response, we launched a Laboratory-wide reengineering effort and undertook other work with the goal of fostering excellence, relevance, and stewardship in all aspects of the Laboratory's operations.

This effort is paying off in improvements in our ability to meet the expectations established for ORNL as a Department of Energy laboratory overseen by the Office of Science: delivering advances in science and technology, securing new capabilities, improving our ability to operate safely and efficiently at reasonable cost, and being a good neighbor. The development of critical outcomes and objectives, now under way in partnership with the Department's Oak Ridge Operations Office, is aimed at providing a performance-based means of determining how ORNL measures up to these expectations.

Progress in 1998

Notable accomplishments in **science and technology** have strengthened ORNL's reputation as a primary provider of research and development (R&D) addressing the missions of the Department and other national needs.

- The 1998 Gordon Bell Prize for Best Performance of a Supercomputing Application was awarded to ORNL (with the Lawrence Berkeley National Laboratory, the Pittsburgh Supercomputer Center, and the University of Bristol) for record-setting performance of a code that performs first-principles simulation of metallic magnetism in iron; the research team has since broken its own record by improving the code's performance to achieve 1.02 teraflops—more than a trillion calculations per second.
- An innovative computerized tomography system developed at ORNL provides high-resolution images of soft tissue and bones in mice and other laboratory animals, giving researchers a new tool for studying genetic mutations.
- A system that can monitor the flow of fissile material in process piping without penetrating the piping will be used in the downblending of uranium from dismantled nuclear weapons in a process for producing reactor fuel from this material. Two systems have been shipped to Russia for installation in downblending facilities.
- Spatial signature analysis technology developed at ORNL for SEMATECH, the U.S. semiconductor industry partnership, reduces defects in electronic components and has been licensed to 14 semiconductor manufacturers and equipment suppliers.
- ORNL researchers are developing the radio-frequency and superconducting magnet systems of the Variable Specific Impulse Magnetoplasma Rocket, or VASIMR, an

innovative rocket engine being developed by NASA's Advanced Space Propulsion Laboratory.

- In partnership with the University of Tennessee, the Department of Energy, and the Development Corporation of Knox County, we will soon begin construction of a facility to house the collaborative National Transportation Research Center.
- A miniature calorimetric spectrometer and a computational tool for functional optimization were selected as R&D 100 award winners in 1998, bringing to 96 ORNL's total number of winners since 1963.
- Dr. Audrey Stevens, a senior ORNL scientist, was elected to the National Academy of Sciences, and two ORNL scientists received Presidential Early Career Awards.

As these examples show, we continue to use partnerships with other Department of Energy laboratories, universities, and industry as a means of leveraging resources, increasing our scientific productivity, and making the Department's resources available to others in the national interest. About 4000 guest researchers worked at ORNL in 1998, many taking advantage of our 15 national user facilities, and nearly 75% of the research articles published by ORNL staff members have coauthors who represent other institutions.

A new Office of Partnerships and Program Development, established as a result of our reengineering efforts, manages key services dealing with partnerships, including technology transfer and Work for Others. It also provides opportunities for linking ORNL's capabilities with those of the Department's Oak Ridge Y-12 Plant. Science education remains another area in which partnerships play a notable role; ORNL continues to offer unparalleled opportunities for students and teachers at all educational levels.

We are enhancing our capabilities for conducting R&D by upgrading existing facilities and developing innovative ways of making our facilities available to users beyond ORNL. New computer analysis techniques for beam tube design will produce substantial gains in neutron scattering intensities at the High Flux Isotope Reactor. A Congressional Expo in 1998 focused attention on the Materials Microcharacterization Collaboratory, a "virtual laboratory" that provides researchers with remote access to leading-edge facilities at ORNL, Argonne National Laboratory, Lawrence Berkeley National Laboratory, the National Institute of Standards and Technology, and the University of Illinois.

We are working to secure **new capabilities** through our major initiatives, described in detail in Sect. 4 of this plan.

The fiscal year (FY) 1999 budget contains construction funding for the Spallation Neutron Source (SNS), the top-priority project of the Department's Office of Science and the centerpiece of our major initiative in neutron science. The SNS will significantly extend the nation's capabilities for studying scientific problems in chemistry, magnetism and superconductivity, materials, structural biology, and engineering. It also brings together the talents and skills of the Department's national laboratories in a cooperative and collaborative mode. In January 1998, during a visit to ORNL, Vice President Al Gore commented, "This project represents not only an advance in science but an advance in the way we approach our science. This is the first time in history that a project of this scope is actually being shared by five national laboratories."

Our functional genomics initiative combines ORNL's mutant mouse stocks, expertise in genetics, and strengths in analytical technologies, bioinformatics, and computational biology to contribute to the exploration of the structure, organization, and function of genetic material. We are working with the Department's Joint Genome Institute and have recently established the Tennessee Mouse Consortium for Functional Genomics, a partnership with

the University of Tennessee, St. Jude Children's Research Hospital, Meharry Medical College, and Vanderbilt University to accelerate the development of mouse models of human diseases. This initiative will benefit from the Department's plans to make a significant investment in a new Center for Biological Sciences at ORNL, beginning with the construction of a new home for ORNL's mouse colony. The Laboratory for Comparative and Functional Genomics will bring this important resource to our main site and replace an aging and inadequate facility at the Oak Ridge Y-12 Plant.

Our simulation science and teraflops computing initiative involves the continuing development, integration, and application of computational capabilities for the solution of challenging scientific and technical problems. It also includes the evaluation of the innovative SRC-6 supercomputer to determine the effectiveness of this type of machine for solving problems critical to the Department's missions. Our efforts in this area will enhance our ability to contribute to the Scientific Simulation Initiative that the Department is now shaping.

Our reengineering efforts are contributing to a continuing emphasis on **safe and efficient operations at reasonable cost.** The prime operational imperative of ORNL is the health and safety of all its employees, guest scientists and engineers, visitors, and the general public. The implementation of integrated safety management into our workplace, which should be complete by September 1999, reflects our commitment to meeting the Department's expectations in protecting the environment and the safety and health of the work force and the public.

Reengineering investments in new systems, tools, and practices that provide our staff members with better ways to do their jobs are also paying off. A commercial off-the-shelf enterprise information system has been installed to replace several finance, project management, acquisition, and human resources systems and to introduce a number of recognized best business practices in these areas. This system "went live" in October 1998, on time and within budget.

In 1996, our long-term program of cost reduction was reinforced by a commitment, made in connection with the Department of Energy's Strategic Alignment Initiative, to reduce costs by $18 million per year for five years. We met this $90 million commitment in 1998, more than two years ahead of schedule. Part of this accomplishment resulted from continuing reductions in our overhead, which has decreased from $170.6 million in FY 1995 to $152.5 million for FY 1998. At the same time, we have increased our investments in Laboratory Directed R&D funding, reengineering, program development, technology transfer, and the Wigner Postdoctoral Fellows Program. The overhead rate has remained essentially constant despite these increases in investment funding and during a period when our overhead base has dropped significantly.

These achievements were supported by a cost savings and avoidance program that is conducted in partnership with the Department of Energy's ORNL Site Office. Our emphasis on **being a good neighbor** includes working with customers and stakeholders to foster communication and trust. The recent transfer of the American Museum of Science and Energy to ORNL's scope of work gives us a new opportunity for communicating the value of the work of the Laboratory, the Office of Science, and the Department of Energy to a wide audience. Our community outreach and community service programs provide an additional means for demonstrating our commitment to being a good neighbor and public partner. ORNL employees, with support from Lockheed Martin Energy Research Corporation, have assisted in the preservation of the Great Smoky Mountains National Park, supported the

Department's Oak Ridge EnvironMENTAL Fair for schoolchildren, and participated in cultural, educational, and economic development programs in East Tennessee.

Looking Ahead

We have made these advances during turbulent times. In April 1998, Bechtel Jacobs Company LLC took responsibility for the Department's environmental management activities in Oak Ridge under a management and integration (M&I) contract. In August 1998, a new Secretary of Energy was sworn in. A new contract for information technology services at the Department's Oak Ridge installations, including ORNL, is scheduled to be awarded in February 1999, and proposals from contractors seeking to provide protective services across the Oak Ridge Reservation will soon be submitted. In December 1998, the Secretary of Energy announced his decision to proceed with a competition for the M&O contract for ORNL. The current contract expires on March 31, 2000.

These changes are creating notable near-term challenges for ORNL. Transfers of personnel and funding, with their associated uncertainties, are affecting working relationships, budgets, and morale. New ways of doing business and new interfaces with contractors carrying out work at the ORNL site must be developed to ensure safe and efficient conduct of operations. The competition of ORNL's M&O contract is likely to entail some disruption in the work of the Laboratory. The long-term impacts of these changes are difficult to predict, but this is clearly a critical period for ORNL.

During the planning period, our primary challenge will be to continue in our efforts to meet the expectations outlined for us in 1996—to sustain ORNL as an outstanding institution where science and technology can flourish, to operate the Laboratory in a safe and environmentally responsible manner, to manage its business functions so as to provide the maximum return on the taxpayers' investment, to foster communication and trust among stakeholders, and to be a good neighbor in the community.

This institutional plan describes how we will work with the Department of Energy to deliver on these expectations during the planning period and beyond.

2 • Mission, Roles, and Capabilities

The Oak Ridge National Laboratory (ORNL) is a multiprogram science and technology laboratory managed for the U.S. Department of Energy (DOE) by Lockheed Martin Energy Research Corporation. In support of DOE's missions, the Laboratory conducts basic and applied research and development (R&D) to create scientific knowledge and technological solutions that strengthen the nation's leadership in key areas of science; increase the availability of clean, abundant energy; restore and protect the environment; and contribute to national security.

2.1 • Support for DOE Missions

As a multiprogram national laboratory, ORNL carries out R&D in support of all four of DOE's major missions: science and technology, energy resources, environmental quality, and national security. The Laboratory plays a principal role in fundamental science and energy resources and applies special capabilities to support DOE's needs in environmental quality and national security. Key R&D activities that support DOE's major missions are as follows.

- **Science and Technology**
  - Analytical and separations chemistry and chemical sciences
  - Environmental and social sciences
  - Functional genomics, proteomics, biotechnology, and bioengineering
  - High-performance computing: computer and computational science, distributed computing, and informatics
  - Instrumentation and measurement science and technology
  - Materials science and engineering
  - Neutron science: neutron scattering, isotope production, and design of accelerator-based and reactor-based neutron sources
  - Nuclear physics and high-energy nuclear astrophysics with radioactive ion beams
  - Plasma science and fusion technology
- **Energy Resources**
  - Biomass: renewable energy feedstock and conversion technologies
  - Energy-efficient technologies for buildings, industrial, transportation, and utility end-use
  - Fossil energy: applied materials and turbines
  - Nuclear technology and safety

- **Environmental Quality**
  - Environmental management science
  - Environmental technology development
  - Health and environmental risk assessment
- **National Security**
  - Management and disposition of weapons-related nuclear material
  - Promoting nonproliferation and international nuclear safety
  - Strategic computing for safe stockpile stewardship

ORNL's institutional strengths in R&D integration enable the Laboratory to focus and leverage its resources and capabilities in programs that cross traditional disciplinary, programmatic, and organizational boundaries. ORNL works extensively with other national laboratories both through traditional collaborative arrangements and increasingly through the development and application of capabilities that facilitate collaboration among geographically separated researchers. The Spallation Neutron Source project, described in Sect. 4.1.1, has been cited by DOE as an outstanding example of interlaboratory collaboration. Other collaborations are discussed in Sect. 2.3.3, "R&D Programs"; in Sect. 3.4, "Strategic Directions," and in Sect. 6.1, "Science and Technology Partnerships."

2.2 • Excellence in Operations

In carrying out its roles, ORNL is governed by eight **operational imperatives**:

- Conduct all operations with due regard for the health and safety of all employees, guest scientists and engineers, visitors, and the general public.
- Conduct all operations in a safe and environmentally responsible manner.
- Adhere to the highest professional and ethical standards in all activities.
- Support the execution of R&D missions with efficient, cost-effective business practices and support services.
- Acquire and sustain the intellectual and physical resources needed to explore challenging scientific and technical problems and provide innovative solutions.
- Collaborate with universities, industry, other DOE laboratories, other federal agencies, and state and regional organizations to create new opportunities.
- Communicate the value of ORNL's R&D activities to a broad audience.
- Respect the value of other people's time.

2.3 • Distinctive Capabilities

ORNL carries out its mission assignments by applying distinctive capabilities developed through and directed toward support for DOE needs. These capabilities flow from pioneering work, unique facilities (see Sect. 2.3.2), and talented staff.

ORNL focuses its capabilities through six areas of R&D emphasis, described in detail in Sect. 2.3.1:

- energy production and end-use technologies;
- neutron-based science and technology;
- advanced materials synthesis, characterization, and processing;
- biological and environmental sciences and technology;
- instrumentation and measurement science and technology; and
- computational science and advanced computing.

Integration of broad technical foundations—in physical, chemical, and materials sciences; biological, environmental, and social sciences; engineering sciences; and computational sciences and informatics—characterizes ORNL's R&D programs, which are described in Sect. 2.3.3.

Four institutional strengths cross-cut the areas of R&D emphasis 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.

2.3.1 • Areas of R&D Emphasis

2.3.1.1 • Energy Production and End-Use Technologies

ORNL is one of the world's premier centers for R&D on energy production, distribution, and use and on the effects of energy technologies and decisions on society. As a primary performer of DOE-sponsored R&D in energy efficiency, the Laboratory applies distinguishing capabilities in materials science, biotechnology, engineering, and technology development and evaluation to transportation systems, biofuels, efficient buildings and building materials, industrial processes, and utilities. ORNL research on fission, fossil, and fusion technologies applies the Laboratory's strengths in physics and engineering to the improvement of existing systems and the development of new science and technology. Unique facilities for energy-related R&D are used both for technology development and for fundamental investigations in the basic energy sciences that underpin the technology work. ORNL's scientific, engineering, environmental, economic, and social science expertise is integrated to supply the information needed in making decisions that ensure a sustainable energy future.

2.3.1.2 • Neutron-Based Science and Technology

Stemming directly from the Laboratory's original mission, ORNL's strengths in neutron-based science and technology include the design and operation of neutron sources (reactors and accelerators) and the use of neutrons in science and technology (neutron scattering, isotope production, neutron activation analysis, materials irradiation, and molecular structure determination). ORNL's facilities provide the world's highest peak thermal neutron flux, the only domestic source of heavy transuranic isotopes, and specialized neutron activation analysis for sensitive measurements of trace elements. Capabilities in this area support fundamental nuclear physics research, studies of material properties, nuclear materials management, development of materials for nuclear fusion and fission, isotope production for industrial and medical applications, and environmental protection.

2.3.1.3 • Advanced Materials Synthesis, Characterization, and Processing

ORNL's strengths in advanced materials R&D support the development of ceramics and composites, metals and alloys, surfaces and thin films, polymers, superconductors, and new techniques for materials processing and characterization. This work advances the materials frontier and provides the underpinning for technologies that support DOE's energy resources mission. Notable characteristics include the integration of basic and applied research, unsurpassed characterization facilities, extensive synthesis and processing capabilities, and broad partnerships with industry.

2.3.1.4 • Biological and Environmental Sciences and Technology

A broad spectrum of disciplinary foundations (biology, chemistry, computational sciences, ecology, engineering, geology, geochemistry, geophysics, hydrology, physics, toxicology, and social sciences) is integrated in interdisciplinary programs aimed at understanding and solving major environmental and health problems related to energy development, production, and use. This area of emphasis is anchored in a strong fundamental research program and extends to applications in human health, biotechnology, environmental protection and remediation, separations science, and studies of global change and sustainable development. Facilities for genetics research, informatics and computational biology, protein engineering and structural biology, biotechnology, bioprocessing, and ecological and environmental studies support extensive industrial and educational outreach programs.

2.3.1.5 • Instrumentation and Measurement Science and Technology

ORNL has broad R&D capabilities in the physical, chemical, electronic, engineering, and computational sciences that combine to provide a powerful institutional capability to address national needs for improved measurement, monitoring, and control systems. Particular strengths include microelectronics and photonics, signal processing and simulation, analytical chemistry and chemical physics, materials characterization, robotics and intelligent systems, and sensors for physical, chemical, biological, and radiological phenomena. Activities include fundamental research for elucidating principles that enable novel advances in the measurement sciences; applied research that improves the accuracy, sensitivity, cost-effectiveness, and practicality of advanced techniques and prototype instruments; and design, fabrication, and installation of one-of-a-kind devices and systems. Integration of these capabilities allows the definition, design, and implementation of new methods and instruments for a variety of ORNL activities: energy production and manufacturing processes, environmental characterization and remediation, biotechnology and human health, and national security and forensic science. At the same time, this area of emphasis enhances ORNL's ability to obtain, process, and analyze the research data needed to support DOE's science missions.

2.3.1.6 • Computational Science and Advanced Computing

ORNL is one of the world's leaders in high-performance computing, related technologies, and selected areas of computational science. As home to one of the world's foremost computing centers, its technological resources include Intel Paragon distributed systems; high-performance, high-capacity storage systems; and high-bandwidth Internet connections. ORNL capabilities are integrated into a computational science program that

supports national research needs in materials science, chemical science and engineering, plasma physics, nuclear physics and transport calculations, geographic information systems, the management of environmental information (including groundwater contaminant transport), informatics, and global climate simulation. These activities complement ORNL's long-standing leadership in the development and application of tools and algorithms for distributed parallel processing. Through collaborative efforts with other institutions, work in this area leads to the creation of innovative means of solving very large problems with geographically distributed resources.

2.3.2 • Major Facilities

An important part of DOE's science mission is to provide large-scale, complex scientific facilities for laboratory, academic, and industrial users. ORNL is home to 15 designated national user facilities—more than any other national laboratory—and to a number of other facilities that are used in executing DOE missions. Major facilities include the following.

- **High Flux Isotope Reactor (HFIR).** The HFIR is one of the world's most powerful research reactor facilities. At its current operating power of 85 MW, it has a peak thermal neutron flux of 2.6×10^{15} $cm^{-2} \cdot s^{-1}$, highest in the world. This gives the reactor unique capabilities for producing important radioisotopes and providing facilities for materials irradiation, neutron activation analysis, and neutron beam scattering studies.
- **Holifield Radioactive Ion Beam Facility (HRIBF).** The HRIBF is the first U.S. radioactive ion beam facility devoted to low-energy nuclear structure and nuclear astrophysics research. It is providing new information on nuclear properties and allowing researchers to make pioneering advances in understanding novas, supernovas, X-ray bursts, and other stellar explosions.
- **Mouse Genetics Research Facility (MGRF).** ORNL's MGRF employs expertise in mouse genetics and mutagenesis, phenotype screening, and high-throughput analytical technologies to generate and analyze mutations that add functional information to specific human DNA sequences. Its extensive stocks of mutant mice are a matchless resource for advancing the understanding of the complex mechanisms underlying the development and functioning of biological systems.
- **High Temperature Materials Laboratory (HTML).** The HTML houses several dedicated laboratories and special equipment for collaborative research on advanced ceramics and alloys. Extensive capabilities for materials characterization support advanced research by a broad user community representing DOE, universities, and industry.
- **Oak Ridge National Environmental Research Park (NERP).** ORNL resources for for environmental research and education include the 22,500-acre NERP, which encompasses a sizable area of protected eastern deciduous forest that contains a number of rare and endangered plant and animal species and several major research facilities: the Walker Branch Watershed Throughfall Displacement Facility, the Global Climate Change Experimental Chambers, the Free Air Carbon Dioxide Enrichment Facility, and specialized hydrology field sites.
- **Center for Computational Sciences (CCS).** The CCS provides resources for scientific computing and simulation through operation of powerful computers, development of data storage and access systems and facilities, and collaborative investigations of innovative computing architectures.

- **Buildings Technology Center (BTC).** Research on building thermal envelope systems and materials is conducted in the BTC, which provides world-class facilities for testing advanced building materials and construction strategies.
- **Radiochemical Engineering Development Center (REDC).** The REDC facilities provide transuranium actinide elements (Np, Pu, Am, Cm, Bk, Cf, Es, and Fm) for research endeavors at DOE national laboratories and installations, academic institutions, and industrial facilities.
- **Surface Modification and Characterization Research Center (SMACRC).** The SMACRC is used for fundamental studies of ion-solid interactions and ion beam processing for advanced thin-film science and technology.
- **Shared Research Equipment (SHaRE).** The SHaRE program provides microanalytical facilities for studies in the materials sciences.

2.3.3 • R&D Programs

As a multiprogram national laboratory, ORNL carries out R&D in support of all four major DOE missions. ORNL also undertakes work that supports other DOE functions and work for other sponsors. Through its Laboratory Directed R&D (LDRD) Program, ORNL supports innovative R&D ideas that have no direct programmatic funding.

2.3.3.1 • Science and Technology

DOE's Office of Science (DOE-SC) is the largest single sponsor of research at ORNL, supporting a broad range of science programs.

Fusion Energy Sciences

ORNL's Fusion Program is a strong and vital component of both the U.S. fusion program and the international fusion community. ORNL conducts experimental research on toroidal confinement of high-temperature plasmas on several large tokamaks and stellarators in the United States and other countries. Theoretical research on high-temperature plasmas uses state-of-the-art computing methods to address transport phenomena, magnetohydrodynamics (MHD) behavior, radio-frequency (rf) heating and current drive, and plasma edge effects. ORNL researchers also develop rf heating and current drive technology and high-speed, frozen pellet fueling technology for fusion research; apply technology in nonfusion areas and transfer technology to the private sector; and contribute to the development of advanced superconducting magnets for fusion and other applications. ORNL provides expertise and support to the International Thermonuclear Experimental Reactor collaboration; is a major contributor to the development of low-activation, radiation-resistant materials for fusion; studies atomic collisions relevant to fusion processes and plasma diagnostics and provides numerical data on atomic and molecular processes relevant to fusion R&D; and conducts a variety of R&D projects applying fusion-related technologies and expertise to other fields such as plasma processing and waste disposal.

ORNL's expertise is well matched to the increased emphasis being placed on innovative confinement concepts by the U.S. fusion program. The U.S. spherical torus program, which originated at ORNL, is now centered on the National Spherical Torus Experiment (NSTX) at the Princeton Plasma Physics Laboratory (PPPL). ORNL expects to be a major participant in the NSTX physics program. In addition, ORNL is deeply involved in the

growing national stellarator program; it is partnering with PPPL to propose the National Compact Stellarator Experiment at PPPL and intends to work with PPPL and at least one university to propose a complementary facility, to be built at ORNL, for exploring the concept of quasi-omnigeneity.

The ORNL Fusion Program will also apply its strengths in collaboration and strategic alliances to the development of the Virtual Laboratory for Technology. This new tool for unifying and coordinating the U.S. effort to meet emerging needs in fusion technology will be governed through a partnership between ORNL and the University of California at San Diego.

High-Energy Physics

ORNL's High-Energy Physics Program is focused on detector design and response data for detector collaborations, on radiation shielding design, and on the development of methods for definitive high-energy transport calculations. Activities include a joint program with the universities of the Southern Association for High Energy Physics and participation in the Main Injector Neutrino Oscillation Search (MINOS) collaboration led by the Fermi National Accelerator Laboratory.

Nuclear Physics

The Nuclear Physics Program emphasizes basic nuclear physics research, both experimental and theoretical, and operation of the HRIBF and the Oak Ridge Electron Linear Accelerator (ORELA) for nuclear physics and the Atomic Physics EN Tandem Accelerator and the Electron Cyclotron Resonance Ion Source facility for atomic physics.

Medium-energy research is concerned primarily with the investigation and characterization of the fundamental modes of nuclear excitation. At higher energies, heavy ion reactions are studied at the European Laboratory for Particle Physics (CERN) in Geneva. ORNL also has a leadership role on the PHENIX detector for the Relativistic Heavy Ion Collider at the Brookhaven National Laboratory (BNL).

ORNL's relativistic heavy ion physics program provides support and guidance for the experimental programs at CERN and BNL. Research in nuclear structure theory takes advantage of the opportunities presented by the joint ORNL–University of Tennessee (UT) nuclear structure theory program. An interdisciplinary project addressing the computational Grand Challenge on the quantum structure of matter supports a new level of computational nuclear structure physics and astrophysics modeling through algorithm development and support for massively parallel calculations.

Efforts in radioactive ion beam (RIB) physics draw on the capabilities of the HRIBF, which is the only U.S. facility that can produce and accelerate high-intensity, low-energy, tandem-quality beams of radioactive nuclei. The nuclear structure program on the HRIBF will extend the studies of nuclear properties to exotic nuclei not now accessible with stable beams. The nuclear astrophysics program will use RIBs to make pioneering advances in the understanding of stellar explosions. As described in Sect. 3.4.2.1, ORNL has unique resources for the construction and operation of a national RIB facility, for which the HRIBF can be considered a prototype.

The ORELA is a unique, intense pulsed-neutron-source accelerator facility for reaction measurements by time-of-flight neutron spectrometry. The ORELA program is directed toward basic research in nuclear astrophysics and fundamental interactions. Measurements

made on ORELA also support DOE's Nuclear Criticality Predictability Program, as described in Sect. 2.2.2.3.

Basic Energy Sciences

The DOE-SC Office of Basic Energy Sciences (BES) supports a broad spectrum of research in the physical sciences at ORNL through its Materials Sciences, Chemical Sciences, and Engineering and Geosciences divisions. Major ORNL endeavors supported by BES include the Spallation Neutron Source (SNS) and the HFIR Upgrade, which are discussed in Sect. 4.1.

The Materials Sciences program supports a comprehensive fundamental materials R&D effort in support of DOE's science and energy missions. An integrated, interdisciplinary approach is emphasized, including major research efforts in neutron scattering, synthesis and characterization of advanced materials, high-temperature materials, ceramic processing, superconductivity, surfaces and thin films, synchrotron research, ion beam and laser processing, and theoretical studies. The program benefits from access to unique, state-of-the-art materials research facilities and from close interactions with materials-related energy technology programs. Major research initiatives include the SNS and the neutron scattering upgrades at HFIR (both described in Sect. 4.1), the development of synchrotron beam lines at the Advanced Photon Source at Argonne National Laboratory, and proposals for an Advanced Materials Characterization Laboratory (see Sect. 3.4.2.2) and a National Center for Crystal Growth (see Sect. 3.4.3.3).

The Materials Sciences program also operates four national user facilities: the SMACRC, the Neutron Scattering Research Facilities at the HFIR, and two programs co-sponsored by ORNL and the Oak Ridge Institute for Science and Education: the SHaRE Program and the Oak Ridge Synchrotron Organization for Advanced Research. These facilities provide specialized research capabilities to hundreds of research scientists and graduate students from universities, industry, and government laboratories.

ORNL is a leader in fundamental materials science and the development of advanced materials, processes, and characterization technologies. The SNS and the HFIR upgrades are addressing a long-term national need for improved neutron science facilities and will provide outstanding opportunities in many fields. A new focus at the HFIR, made possible by the new cold source, will be soft condensed matter research. New microbeam capabilities at the Advanced Photon Source will extend the understanding of materials phenomena to mesoscale length scales. Other new research directions include ultrahigh-temperature intermetallics, ceramic surfaces and interfaces, and the effects of reduced dimensionality and nanoscale geometries on materials properties. The proposed Advanced Materials Characterization Laboratory and National Center for Crystal Growth will address ORNL and national needs in materials characterization and synthesis.

The Materials Sciences program also advances the understanding of materials and materials-related phenomena that underpin energy technologies. Basic research in materials sciences is integrated with the R&D efforts of DOE's applied 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 energy sciences program in DOE-SC. Key endeavors that benefit from materials R&D include the Partnership for a New Generation of Vehicles and environmental technology development programs.

The Chemical Sciences program supports the operation of the HFIR/REDC complex. The HFIR, which provides the highest steady-state flux of thermal neutrons in the world, is used for neutron activation analysis, materials irradiation, the production of isotopes, and neutron scattering R&D. Neutrons from the HFIR are vital to research in the materials sciences, chemical sciences, magnetic fusion, and biology programs at ORNL and for external users and collaborators. Each year approximately 400 researchers use its facilities. Activities at the REDC involve the development and use of production processes and product forms for radioisotopes, predominantly the isotopes of transuranium elements.

The Chemical Sciences program also supports programs in molecular processes, which feature particular strengths in mass spectrometry, properties of high-temperature aqueous electrolyte solutions, separations chemistry and chemical engineering, organic chemistry of energy resources, and actinide science. Current research emphases include improved understanding of chemical conversions that underpin new or existing concepts for energy utilization and conversion; exploration of the chemistry and physics required to conceptualize new analytical methods; use of molecular recognition concepts to design selective separations involving solvent extraction; unraveling the systematics of the solid-state behavior of actinide elements and compounds; relating the thermodynamic properties of aqueous solutions at extreme conditions to molecular structure; and advanced battery concepts.

Research in experimental and theoretical atomic physics completes the Chemical Sciences portfolio at ORNL. The experimental effort is focused on studying interactions of highly charged or molecular ions with gas and solid targets and with electrons. Collision energies range from 2 meV to 33 TeV. Intimately coupled with the experimental work are theoretical studies of the dynamics of strongly perturbed atomic systems, which involve the development of new physical models and mathematical and computational techniques. Strong connections to experimental programs at ORNL and other laboratories are maintained; particular attention is focused on fundamental and complex systems that play a role in energy research.

The BES Engineering Research program sponsors two activities at ORNL: an investigation of the engineering principles governing the operation of liquid-liquid emulsion bioreactors and the Center for Engineering Systems Advanced Research (CESAR). CESAR's primary mission is to develop a core of excellence in the area of intelligent systems technology, supporting the needs of DOE (see Sect. 3.4.3.4) and other customers. Geoscience research at ORNL focuses on fundamental geochemical processes that control matter and energy transport in the earth's crust.

Computational and Technology Research

The DOE-SC Office of Computational and Technology Research (OCTR) supports ORNL research in and application of mathematical, computational, computer, and communications sciences. This includes the operation of the CCS and the conduct of basic research through the Applied Mathematical Sciences (AMS) subprogram. The teraops computing and simulation science initiative described in Sect. 4.3 will extend ORNL resources and expertise to support DOE's missions in science and national security. The AMS program supports research in parallel processing algorithms; tools to facilitate the use of parallel and distributed computing systems; and development of applied mathematical, statistical, and computational methods for analyses of physical processes. ORNL's Collaborative Technologies Research Center, described in Sect. 3.4.4.4, provides a means for ORNL to team with

universities, other laboratories, and industry partners in building capabilities for telepresence and collaborative environments.

With OCTR support, ORNL is participating in the DOE2000 initiative to create and apply new computational tools and libraries that advance the concept of "national collaboratories" and advanced computational testing and simulation (ACTS). Activities include the Materials Microcharacterization Collaboratory (MMC); the neutron scattering virtual laboratory based on the DIXIE instrument at the HFIR; the ACTS Scientific Template Library; the Electronic Logbooks project; and the Collaborative Management Environment project.

Through the MMC, resources at ORNL, the Argonne and Lawrence Berkeley national laboratories, the National Institute of Standards and Technology (NIST), and the University of Illinois at Urbana-Champaign are available to a wide user community through electronic collaboration. The MMC is supported by OCTR, BES, DOE-EE, NIST, and industry.

OCTR also supports innovative, high-risk research that does not fall under the auspices of other DOE programs. The Advanced Energy Projects Program is funding projects on biomolecular optoelectronic devices, electrically active liquid matrix composites, and shape memory alloy reinforcement of metals. The Energy Research Laboratory Technology Research Program supports research that integrates basic and applied disciplines to promote substantial changes in technologies of strategic importance to DOE's missions and American industry. Activities include cooperative R&D agreements and collaborations with other national laboratories (see Sect. 6.1). ORNL researchers are working with Brookhaven National Laboratory and InnerDyne, Inc., on a new means of preventing restenosis after coronary balloon angioplasty; with the Argonne National Laboratory and several automotive companies to apply computational fluid dynamics in developing models for simulating complex systems in high-efficiency automobiles; with partners from the steel industry to develop infrared processing technology to improve the energy efficiency of the forging of steel; and with Perkin-Elmer and the University of Tennessee to provide wireless luminescence integrated sensors for areas ranging from environmental monitoring and assessments to screening new drugs.

Biological and Environmental Research

The ORNL Biological and Environmental Research (BER) Program, under the sponsorship of the DOE-SC Office of Biological and Environmental Research (OBER), is one of the broadest multidisciplinary life sciences research programs in the nation. Goals of the ORNL BER Program are to

- study the interaction of energy-related physical and chemical agents with living organisms and the environment, including their transport, chemical transformations, adverse health effects, and ultimate consequences to humans and the environment;
- explore the functional genomics of human, other mammalian, plant, and microbial genomes;
- contribute to DOE's Nuclear Medicine Program and other beneficial applications through leveraging with advances in molecular biology and other rapidly developing fields; and
- transfer research findings and technological developments to the private sector.

Research in the life sciences addresses the understanding of complex biological systems and includes functional genomics and mammalian genetics, biochemistry, biophysics, toxicology and risk analysis, nuclear medicine, biomedical technology development, and

computational biology and informatics. The major Laboratory initiative in functional genomics, described in Sect. 4.2, is an integrated activity that draws on resources from these and other ORNL programs.

Environmental science research covers biogeochemistry, environmental biotechnology, global environmental chemistry, ecosystem studies, geosciences, hydrology, and environmental assessment. As described in Sect. 3.4.2.3, ORNL capabilities, some developed in support of other missions, will be focused on the task of overcoming major scientific uncertainties in the understanding of large-scale environmental issues. Expanded work in global climate change and carbon sequestration (see Sect. 3.4.2.5) will also bring ORNL's distinctive capabilities in the biological and environmental sciences and technologies to bear on DOE strategic goals.

Three user facilities contribute to the ORNL BER Program: the Mouse Genetics Research Facility, the Oak Ridge National Environmental Research Park, and the Bioprocessing R&D Center. The ORNL Center for Biotechnology (see Sect. 3.4.4.1) provides a coordinated focus for the Laboratory's extensive biotechnology activities in the areas of biomedical sciences, environmental sciences, and bioprocessing. The ORNL Center for Global Environmental Studies (see Sect. 3.4.2.5) integrates the Laboratory's science and technology to understand environmental processes and support sustainable development.

2.3.3.2 • Energy Resources

Energy Efficiency and Renewable Energy

ORNL's Energy Efficiency and Renewable Energy (EE/RE) Program facilitates R&D on energy efficiency and renewable energy technologies. The major source of program funding is DOE-EE. The program employs an integrated approach to achieve its 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.
- It involves a wide array of industrial, academic, and public-sector partners in the definition, execution, and assessment of its activities.

Major R&D areas for the EE/RE Program are buildings technologies, transportation technologies, industrial technologies, and utilities technologies.

Buildings Technologies • ORNL research in buildings technologies spans several areas. Heat pump, chiller, and refrigerator technologies are examined to improve energy efficiency and environmental quality. The search for viable alternatives to chlorofluorocarbons (CFCs), which may contribute to global warming, is an important part of both equipment and materials research. CFCs are used both as working fluids for heating and cooling equipment and in the manufacture of some insulations. Materials research focuses on technologies for CFC-free, high-efficiency, long-lived building insulations. ORNL's building envelope research examines how buildings function as a system—how roofs, walls, windows, and other building elements interact to affect energy efficiency. Researchers also conduct R&D on innovative walls, roofs, and foundations. Retrofits to improve energy efficiency in existing buildings are studied to determine how to obtain the most cost-effective results. A related activity is R&D on improved energy audits and energy use monitoring techniques. Other research areas include manufactured housing and technical assistance with the incorporation of innovative materials and technologies in buildings.

ORNL provides technical support to the Federal Energy Management Program in the demonstration of new technologies, energy audits in federal buildings, and establishment of a Super Energy Saving Performance Contract to facilitate energy-related improvements in federal buildings in the southeastern United States.

Transportation Technologies • Transportation R&D in the ORNL EE/RE Program includes materials, ignition and combustion, alternative fuels, and innovative manufacturing and finishing processes. Most of the transportation R&D is related to the Partnership for a New Generation of Vehicles (PNGV), which has three goals: to significantly improve national competitiveness in manufacturing, to pursue changes in today's vehicles that will improve efficiency and lower emissions while maintaining safety and performance, and to achieve, within a decade, improvements in fuel efficiency up to three times that of the average 1994 Taurus/Concorde/Lumina–type sedan, with a competitive purchase price. ORNL is developing agricultural crops with increased yields, pest and disease resistance, and drought tolerance for conversion to transportation fuels. ORNL's transportation expertise is also applied to the needs of other sponsors, as described in Sects. 2.3.3.6 and 3.4.4.2.

Industrial Technologies • Seven major industries—glass, chemicals, petroleum refining, aluminum, forest products, metalcasting, and steel—provide materials for the rest of the U.S. manufacturing sector and, in the process, account for about 27% of the nation's total energy use. ORNL is participating in DOE's Industries of the Future initiative, which assists these primary industries and the agriculture industry in cutting their nonproductive energy use and environmental costs. Development of new materials that can better withstand the high temperatures and highly corrosive environments often found in industrial processes is a key area of research. ORNL leads materials R&D for ultrahigh-efficiency, clean, cost-competitive gas turbines. Technology support to the DOE Motor Challenge Program includes the development of measurement and validation tools and techniques. New equipment and processes are investigated, ranging from improvements in heat transfer equipment to "bioreactors" that convert sugars (instead of today's petroleum feedstocks) to industrial chemicals. Other research is concerned with heat pump and chiller technologies.

Utility Technologies • During the past several decades, electricity's share of U.S. primary energy use has been steadily increasing, to about 35% of the total in 1994. ORNL is helping to find ways of ensuring that electricity is delivered efficiently and safely and that cost-effective renewable resource options are available. Research areas include investigation of reported health effects of electric and magnetic fields, power electronics, high-temperature superconductivity, power transmission and distribution, hydropower environmental mitigation, and hydrogen supply (including infrastructure issues). ORNL is addressing technology needs for using biomass in existing power plants to supplement or replace coal. ORNL also has expertise in research, analysis, and outreach activities associated with the design and evaluation of demand-side management programs, electric utility resource planning, and impacts of the increasingly competitive power market. Expected activities in clean power generation are described in Sect. 3.4.2.4.

Four national user facilities are available to researchers: the Bioprocessing R&D Center, the BTC, the HTML, and the Materials Processing Laboratory User Center.

ORNL is a partner in the Energy Efficiency and Renewable Energy Network, a joint project involving DOE-EE, Argonne National Laboratory, ORNL, and the National Renewable Energy Laboratory.

Fossil Energy

ORNL programs for DOE-FE cover research in coal, gas, petroleum, and innovative clean coal technology, plus support to the Strategic Petroleum Reserve.

The Fossil Energy Advanced Research and Technology Development Materials Program covers (1) development of ceramic composites for high-temperature applications, (2) development of alloys with unique properties for advanced fossil energy systems; (3) development of ceramic filters, ceramic membranes, and carbon materials; and (4) corrosion research to understand the behavior of materials in coal processing environments. Petroleum bioprocessing research explores the treatment of petroleum, petroleum-derived products, and effluent streams to remove contaminants. ORNL research also includes the production of molecular hydrogen via photosynthetic water splitting, investigation of the biological quality of soils containing hydrocarbons to reduce ecological risks through bioremediation, and studies on crude oil composition and oil recovery. Coal combustion research involves analysis of fluidized-bed combustion data for deterministic chaos.

ORNL participates in the Advanced Turbine Systems Program sponsored by DOE-FE and DOE-EE and addresses materials and manufacturing issues for gas turbines. Advanced membrane technology is being extended to the separation of hydrogen from refinery gas streams.

For the Clean Coal Technology Program, ORNL provides environmental technical support and materials failure analyses to the Federal Energy Technology Center. ORNL also assists the Strategic Petroleum Reserve program in the development of models for planning the capacity and management of the reserve and for analyzing the oil market. Research is also performed to develop advanced computational tools for three-dimensional seismic analysis.

Nuclear Energy, Science and Technology

ORNL programs for the DOE Office of Nuclear Energy, Science and Technology (DOE-NE) include nuclear energy R&D and isotope production and distribution.

ORNL supports DOE's policy and strategy initiatives to define the appropriate role for nuclear energy in the nation's future energy supply. The Laboratory leads DOE-NE's principal R&D activity under the Joint Agreement with Japan's Nuclear Power Engineering Corporation, a cooperative activity that involves the development and demonstration of robotics for surveying and mapping radioactive contamination and decontaminating and dismantling nuclear power plants.

ORNL expects to contribute to DOE's Nuclear Energy Research Initiative, beginning in FY 1999, in four key areas: (1) development of nuclear technologies for existing light water reactors (LWRs) to offset CO_2 emissions, (2) development of proliferation-resistant technologies such as thorium-based fuels for LWRs, (3) R&D in advanced materials and advanced sensors and controls to underpin the science base of U.S. nuclear technology, and (4) development of advanced fuel clad materials that enable high-burnup fuels and spent fuel minimization.

ORNL also supports key objectives in uranium programs through activities such as developing technology and providing systems for the verification of highly enriched uranium blend-down in Russian Federation facilities and serving as lead laboratory for the identification and development of beneficial uses for depleted uranium.

ORNL supports the production of parts for radioisotope power systems supplied to the National Aeronautics and Space Administration (NASA), providing the materials processing and precision fabrication required to produce the iridium clad vent sets and the carbon-carbon holders. ORNL is studying an option to meet long-term needs for an assured supply of ^{238}Pu by irradiation of ^{237}Np targets, both in the Advanced Test Reactor (ATR) at the Idaho National Engineering and Environmental Laboratory and in the HFIR at ORNL. ORNL would fabricate the ^{237}Np targets for both ATR and HFIR irradiations and would provide chemical processing of the targets for material recovery at the REDC. ORNL is also being considered as the national repository for storage of the DOE inventory of ^{237}Np oxide.

ORNL's Isotope Production and Distribution Program supplies enriched stable isotopes, selected radioisotopes, and related technical services for research, medical, and industrial applications. The program mission includes the development and evaluation of methods of isotope production and separation. ORNL also provides specialized technical services (e.g., preparation of high-purity isotopes and unique chemical and physical forms). Capabilities and opportunities in this area are described in Sects. 3.4.3.2 and 3.4.3.3.

Power Marketing Administrations

ORNL conducts program evaluation research for the Bonneville Power Administration and provides technical support in evaluating and mitigating the effects of Bonneville's operations on fish populations.

Energy Information Administration

ORNL provides analytic and technical support to the Energy Information Administration (EIA) and advises EIA of resources available within ORNL to support EIA programs.

2.3.3.3 • Environmental Quality

Environmental Management

DOE's Office of Environmental Management (DOE-EM) provides funding to ORNL for R&D and technical support for addressing environmental management problems, principally at DOE sites, with increasing emphasis on technology transfer. Some of this work is funded through Bechtel Jacobs Company LLC, which manages DOE's Environmental Management and Enrichment Facilities (EMEF) Program in Oak Ridge under a management and integration contract. During the planning period, ORNL expects to continue to support the EMEF Program through agreements with Bechtel Jacobs.

ORNL supports DOE-EM remedial action projects by characterizing and verifying the radiological status of sites involved. Advancing the state of the art in equipment and methodology is an integral part of this work. ORNL also supports DOE initiatives to release decontaminated facilities through work that supports the establishment of well-documented criteria for facility release.

ORNL supports DOE-EM program needs through the development and implementation of technologies to (1) facilitate compliance with environmental laws, regulations, and agreements; (2) clean up contaminated DOE sites at less cost than current technologies; (3) minimize the toxicity and volume of waste; (4) manage unavoidable waste more efficiently and safely; and (5) achieve safe, permanent disposal of waste within regulatory guidelines. Efforts focus on four major problem areas: subsurface contamination; mixed waste

characterization, treatment, and disposal; high-level waste tank remediation; and facility transitioning, decommissioning, and final disposition.

ORNL supports DOE's Nuclear Criticality Safety Program (NCSP), which was developed in response to Defense Nuclear Facility Safety Board Recommendations 93-2 and 97-2. ORNL performs the lead role in the Nuclear Data Element of the NCSP by measuring neutron cross sections with the Oak Ridge Electron Linear Accelerator (ORELA), evaluating the measured data with the SAMMY code, and testing the evaluations in conjunction with the Cross Section Evaluation Working Group. ORNL coordinates the work program of the Analytical Codes Element by providing capability maintenance and training and user assistance in the SCALE/KENO code system. ORNL is also performing a special NCSP study, "Guidance for Applicability of Bounding Curves/Data." The NCSP is a cross-cutting, multilaboratory program, led by DOE's Office of Defense Programs with additional funding from other DOE organizations. ORNL efforts are primarily funded by DOE-EM; DOE-SC and the DOE Office of Environment, Safety and Health also contribute to the NCSP budget.

ORNL scientists are developing technologies that can be applied to multiple classes of problems through innovative, cross-cutting programs in characterization, monitoring, and sensor technologies; separations and processing technologies (see Sect. 3.4.3.3); and robotics technologies (see Sects. 3.4.3.4 and 3.4.4.3). R&D projects are also conducted to improve the safety, compliance, and effectiveness of DOE's transportation of hazardous and radioactive materials. Some of this work is supported by DOE's Environmental Management Science Program, a collaborative initiative administered by DOE-EM and DOE-SC that sponsors basic research to establish the scientific and engineering understanding required to solve the challenging problems presented by DOE's environmental cleanup program.

Environment, Safety, and Health

ORNL provides support to the DOE Office of Environment, Safety and Health in the categories of oversight, policy and standards, technical assistance, health studies, and information resource management. R&D and technical support activities are coordinated by a program manager and span many ORNL divisions and organizations. Activities include technical standards, criticality safety analysis, performance indicators, occurrence reporting quality, environmental policy and assistance, environmental impact assessment and National Environmental Policy Act (NEPA) compliance, occupational safety and health, facility disposition safety and health support, epidemiology and health surveillance, and business performance systems. These programs are described in detail in *ORNL Research and Technical Support Programs Funded by DOE's Assistant Secretary for Environmental, Safety and Health, FY 1997,* available on line at <http://www.esd.ornl.gov/LSET/EH>.

2.3.3.4 • National Security

Defense Programs

ORNL's work for DOE's Office of Defense Programs (DOE-DP) includes support for nuclear weapons R&D, strategic computing, facility transition, and the Accelerator Production of Tritium (APT) program.

ORNL produces ^{252}Cf in the HFIR through an Industrial Sales/Loan Program co-sponsored by DOE-SC. Transuranium element isotopes are recovered from Mark 42 targets, purified, and used in weapons diagnostics at Los Alamos National Laboratory (LANL).

ORNL's Radiochemical Development Facility provides shielded, safeguarded storage of ^{233}U, which has been used in diagnostics for weapons testing by DOE-DP. Section 3.4.3.2 details ORNL's capabilities in ^{233}U utilization and operations and describes some emerging opportunities in this area.

The goal of the High-Performance Storage System (HPSS) development project is a network-centered system capable of parallel data transfers at rates in the gigabyte-per-second range. The project links Lawrence Livermore National Laboratory (LLNL), Sandia National Laboratories (SNL), LANL, and ORNL with industrial partners. HPSS is an essential component of DOE's Accelerated Strategic Computing Initiative, and ORNL has a central responsibility in the HPSS Storage System Management system.

ORNL supports DOE-DP in the development and use of models to check cost estimates for major weapons complex facilities and assists DOE-DP in independent evaluations of new tritium production alternatives, as well as supporting materials qualification and software quality assurance for the APT program.

ORNL also provides environment, safety, and health (ES&H) support related to the cleanup of nuclear weapons manufacturing facilities and provides assistance as needed with emergency preparedness activities. ORNL's Radiation Safety Information Computational Center (RSICC) provides information and technology that contribute to the solution of problems occurring in programs for R&D, military application and stockpile support, and facility transition and technical support. The RSICC also receives funding from DOE-NE, DOE-EM, and DOE-SC's Offices of Fusion Energy Sciences and Basic Energy Sciences and from the Defense Special Weapons Agency (DSWA). Its integration of developments in the various programs supports the information and technology needs of all scientists and engineers doing radiation transport calculations.

Fissile Materials Disposition

Under the sponsorship of the DOE Office of Fissile Materials Disposition, ORNL is DOE's lead laboratory for nuclear-based technologies for fissioning surplus plutonium in existing power reactors in the United States, Russia, and possibly Canada. ORNL's roles for the disposition of U.S. materials include (1) R&D needed to convert and license U.S. LWRs for use in turning surplus weapon-grade plutonium into spent fuel and (2) technical support to the DOE procurements of a mixed-oxide (MOX) fuel fabrication facility and irradiation services to burn MOX fuel in commercial LWRs. Critical research at ORNL includes tests to define compatibility issues associated with interactions between gallium fuel impurities and LWR clad materials. ORNL is also managing a multilaboratory, multinational irradiation test program to demonstrate the feasibility of using CANDU reactors for the fissioning of U.S. and Russian surplus plutonium. ORNL is responsible for managing and cooperating with Russia in developing the technology needed to fission Russian plutonium in Russian and Ukrainian VVER-1000 pressurized water reactors and in performing the design and safety analyses needed to convert the Russian BN-600 liquid metal reactor from a plutonium breeder to a plutonium burner. Finally, ORNL is responsible for the technical effort to assist DOE in collecting and analyzing data for the environmental impact analysis of options for disposition of surplus ^{233}U. This activity draws on capabilities described in Sect. 3.4.3.2.

Nonproliferation and National Security

The Office of Nonproliferation and National Security supports R&D activities and technical assessments related to national security requirements. These include work related to chemical sciences and technology, metals and ceramics, instrumentation and controls, engineering technology, biology and health sciences, computational physics and mathematics, energy, robotics and process systems, and solid state physics.

2.3.3.5 • Other DOE Programs

ORNL provides support to other DOE offices and installations, including other DOE contractors and operations offices.

Work for the Office of Policy and International Affairs includes research on transportation, energy efficiency, alternative fuels, fuel economy standards for automobiles and light trucks, and energy options for developing nations. Additional support is provided in regulatory analyses for hydropower development and environmental compliance issues.

ORNL assists the Federal Energy Regulatory Commission (FERC) in (1) environmental, economic, and engineering assessments that support licensing of nonfederal hydroelectric projects, and (2) studies related to compliance with FERC license conditions or other environmental regulations at existing projects. 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.

ORNL performs numerous small tasks, frequently on an ad hoc basis, for a number of other organizations within DOE. These activities are distributed among the various Laboratory programs and make up about 5% of ORNL's total funding.

2.3.3.6 • Work for Others

Federal Organizations

Nuclear Regulatory Commission • ORNL supports the Nuclear Regulatory Commission (NRC) in nuclear safety, safeguards, and environmental protection activities and by providing a technical basis for the NRC's licensing and other regulatory actions and decisions. More than 50 projects are administered through the NRC Programs Office; work is carried out by nine ORNL divisions and two Lockheed Martin Energy Systems, Inc., organizations. These projects are carried out in agreement with the Memorandum of Understanding established between DOE and NRC in 1978, and the work is conducted primarily for the NRC Offices of Nuclear Regulatory Research (RES), Analysis and Evaluation of Operational Data (AEOD), Nuclear Material Safety and Safeguards (NMSS), and Nuclear Reactor Regulation (NRR).

Research areas for RES include reactor pressure vessel (RPV) integrity (irradiation embrittlement, fracture mechanics assessment methodology, pressurized thermal-shock assessments, annealing studies, etc.), nuclear plant aging and license renewal issues, severe accident modeling and analysis, instrumentation and controls technology, and technology supporting advanced reactor certification. ORNL is a leader in the development and application of fracture mechanics technology for nuclear RPVs, in radiation experiments and embrittlement assessments, in boiling water reactor (BWR) core melt progression analysis, in testing techniques to assess component aging, and in microstructural examination methods.

Some of this work is carried out in collaboration with other DOE laboratories and with researchers in other countries.

ORNL projects for AEOD focus on the collection, review, analysis, and evaluation of plant safety performance data. The Accident Sequence Precursor (ASP) program 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 the events. ORNL is assisting in the resolution of operational performance issues, benchmarking the operating records of 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 of reportable operational events at commercial nuclear power plants. This highly structured system, available to NRC staff via the World Wide Web, provides detailed searching of operational events. SCSS supports the ASP program, the NRC's Performance Indicator Program, quantification of common-cause failures, and hundreds of ad hoc queries each year from NRC staff. ORNL also supports the Performance Indicator Program by evaluating operational events to identify and document potential programmatic deficiencies and licensee corrective actions so as to readily ascertain adverse trends in performance.

Research areas for NMSS include criticality safety, shielding and thermal analyses of nuclear fuel facilities and cask designs, environmental review of licensee facilities, review of terminated materials handling license files, and assessment of regulatory needs and tools for material protection, control, and accountability (MPC&A).

Technical assistance is provided to NRR in the areas of fuel stability analyses, economic analyses, component assessments, reviews of safety-related systems, nuclear plant license renewal issues, nuclear reactor licensing actions relative to design basis and severe reactor accident source terms, fission product chemistry, iodine evolution and pH control, and analyses of nuclear plant safety due to loss of offsite power.

U.S. Department of Defense • ORNL provides R&D support to the defense and national security community in areas where its capabilities are applicable to the mission of the Department of Defense (DOD) and related security agencies. Programs are conducted in close cooperation with Lockheed Martin Energy Systems, Inc., and include basic and applied research and technology demonstration programs.

ORNL provides special high-strength, lightweight materials for advanced armor for protection of civilian and military personnel, armored vehicles, satellites, and other high-value assets. Advanced material processing also supports development of new penetrators and penetration systems, high-temperature nose cones, and related weapon components. ORNL also performs research on advanced materials and processing for microelectronics.

Work continues to develop miniaturized sensors, intelligent sensors on a chip, and battlefield-portable mass spectrometers for point contact and stand-off detection of chemical and biological agents. New instrumentation and sensors are also being developed to improve detection of land and marine mines from land-, air-, and marine-based systems. This work is conducted in collaboration with other DOE national laboratories (see Sect. 3.4.4.3).

Improved diagnostic and prognostic systems support the manufacture, life extension, and maintenance of weapon systems. Novel approaches to secure communications and computing are being developed for the safe transmission of information for national security and business applications.

Autonomous and teleoperated robotic systems are developed for remote navigation in hazardous environments for site characterization and restoration and for safe handling of hazardous materials. Remote handling technologies are also used to rearm ammunition for military ground combat vehicles, aircraft, and air defense missile systems.

Work continues to develop transportation and logistics models for defense customers, including transportation planning and tracking for rapid military response planning and execution for international contingencies. Environmental research is conducted to better manage military base operations and to support the closing, restructuring, and modernization of military bases and facilities. New technology is developed and evaluated to avoid or reduce pollution from DOD manufacturing programs. Energy research supports new energy conservation technology for military housing and power supply systems, as well as more efficient vehicle and transportation systems. Work continues to provide demographic and economic modeling support for planning, recruiting, and retention of military personnel.

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 through which the scientific research community can acquire data and information from EOSDIS. ORNL is also supplying radio-frequency technology for an advanced rocket engine and assisting in data compilation on the growth of vegetation.

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, bioanalytical chemistry, genetics, and toxicology. The majority of funding is from the National Institutes of Health; some funding is from the U.S. Food and Drug Administration (FDA). ORNL conducts research for the National Cancer Institute; the National Heart, Lung, and Blood Institute; the National Institute on Aging; the National Institute for Environmental Health Sciences; and the National Institute of General Medicine. The National Institute for Child Health and Human Development supports a program on insertional mutations and also sponsors research on fundamental cryobiology and preservation of mouse sperm. For the National Institute of Allergy and Infectious Diseases, ORNL is investigating a mouse autoimmune disease that may be a model for disorders of the human immune system. ORNL also studies 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. Genetic, reproductive, and general toxicology databases are developed, analyzed, and evaluated for the FDA, the National Library of Medicine, and the National Toxicology Program, with support from the Environmental Protection Agency (EPA).

U.S. Environmental Protection Agency • ORNL's work for the EPA addresses numerous health and environmental problems and issues. Activities include evaluation of the cost-effectiveness of reducing nitrogen oxide emissions as a means of ozone control; support for ecological risk activities; collaboration with EPA scientists on the Design for the Environment Program; evaluation of physiologically based pharmacokinetic models in risk assessment; continuing work on the Environmental Mutagen Information Center database; preparation of literature reviews and chemical hazard information profiles for selected topics and chemicals; maintenance of the Chemical Unit Record Estimates (CURE) database; field validation of analysis methods; and development of reference dose and reportable quantity profiles to reduce uncertainty in risk assessments.

National Science Foundation • The National Science Foundation (NSF) supports the following activities.

- Studies of spatial gradients in nutrient cycling and their effect on stream ecosystem stability. The results will benefit studies of disturbed aquatic systems on the Oak Ridge reservation that are being conducted in concert with remedial actions.
- Research to evaluate the scientific basis for assumptions used in risk assessment. Results are intended for use by federal agencies responsible for regulating human exposure to chemical carcinogens.
- Development of methods for maintaining genetic lines of *Drosophila* in a frozen state.
- Free-air carbon dioxide enrichment (FACE) studies of a closed-canopy deciduous forest at the ORNL FACE Facility in the Oak Ridge National Environmental Research Park.

The NSF also provides funding for the National Center for Environmental Decision-Making Research at the Joint Institute for Energy and Environment, a partnership of ORNL, UT, and the Tennessee Valley Authority (TVA).

ORNL provides technical assistance to the NSF Division of Polar Programs in evaluating the environmental impacts of the U.S. Antarctic Program.

Federal Emergency Management Agency • ORNL programs for the Federal Emergency Management Agency include a range of R&D and technical assistance activities that support national preparedness for disasters and emergencies. ORNL serves as an independent center of expertise in areas from engineering assistance to analysis and assessment.

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. ORNL's activities include research; analysis; technical assistance; project development, implementation, and evaluation; and information dissemination.

U.S. Department of Transportation • The Department of Transportation provides funding to the National Transportation Research Center (see Sect. 3.4.4.2) and supports the ORNL Center for Transportation Analysis. ORNL assists 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 transportation systems. ORNL also provides technical assessment of oil and gas pipeline systems throughout the United States for compliance with regulatory standards.

Other Federal Agencies • ORNL provides technical support to a variety of other federal agencies, including the U.S. Department of Agriculture, the U.S. Department of Commerce, the U.S. Department of the Interior, and the U.S. Department of State.

The State Department provides support for work performed for the International Atomic Energy Agency and the United Nations Educational, Scientific, and Cultural Organization (UNESCO). ORNL assists the U.S. country studies program in support of the Intergovernmental Panel on Climate Change. The Laboratory 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.

In support of the Coastal Change Analysis Project, sponsored by the Coastal Services Center of the National Oceanic and Atmospheric Administration, ORNL conducts R&D on land-cover monitoring in the coastal regions of the United States.

ORNL is assisting TVA in an assessment of the potential for biomass energy within the TVA power system.

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 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 hydropower impacts on fish and wildlife and instream flow policies.

Under the sponsorship of the interagency Strategic Environmental R&D Program, ORNL staff have been involved in the formation of an interagency group including DOE, DOD, the Army, the Navy, the Agency for Toxic Substances and Disease Registry, and the EPA. The group's purpose is to improve the scientific methods and models for the performance and application of risk assessments.

Nonfederal Organizations

ORNL performs research for and in collaboration with many nonfederal entities, both public and private (see Sect. 6.2). These efforts support DOE's aims in developing partnerships and applying the resources of the national laboratories to issues and problems of national importance.

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. This research includes a program on compensatory mechanisms in fish populations, complementing work for DOE's Hydropower Program; analysis of the potential of biomass feedstock for electric power plants, which involves interaction with DOE's Bioenergy Feedstock Development Program; a project cofunded by DOE and EPRI to develop and demonstrate intelligent control systems for nuclear power plants; and technology development in high-temperature structural design methods and fracture assessment procedures for advanced reactors and other high-temperature power plant components, the results of which support DOE's reactor programs. Associated with EPRI research is work funded by Babcock and Wilcox (B&W) for the development of a control algorithm that will be implemented by the B&W Owners Group on new digital control hardware.

Other Nonfederal Organizations • Private industry interacts with ORNL through cooperative R&D agreements, user agreements, licensing agreements, and other mechanisms. ORNL also interacts with many other nonfederal entities, including SEMATECH, the Japan Atomic Energy Research Institute, the Korea Atomic Energy Research Institute, the United Kingdom Atomic Energy Agency, the International Atomic Energy Agency, and Oak Ridge Associated Universities.

2.3.3.7 • Laboratory Directed R&D Program

ORNL's LDRD Program provides 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 (see Sect. 6.3.1). The program operates under the authority of DOE Order 413.2, "Laboratory Directed Research and Development" (March 5, 1997). It is funded by DOE through an overhead charge to all other Laboratory programs. All LDRD project funding requires the approval and authorization of the Laboratory director. The annual program plan for the LDRD Program, which is prepared and submitted to DOE-SC in accordance with DOE Order 413.2, serves to request LDRD funding for the Laboratory and to provide a general description of and justification for the LDRD program. The *ORNL Laboratory Directed Research and Development Program: Annual Report to the Department of Energy Summarizing Fiscal Year 1997* (ORNL/PPA-98/1, March 1998) provides a program overview, funding summaries, and project summaries for the LDRD Program.

3 • Laboratory Strategic Plan

3.1 • Vision

The Oak Ridge National Laboratory (ORNL) will advance the frontiers of science and technology through broad interdisciplinary research and development (R&D) programs that answer fundamental questions, solve technical problems, and address societal needs.

3.2 • Planning Assumptions

- National priorities for R&D will reflect pressing needs in high-priority areas (e.g., communications, environmental protection, health care, manufacturing, national security, transportation).
- The debate on the proper role of government in R&D, which is fueled in part by the urgent focus on reducing the federal deficit and federal spending of all kinds, will continue.
- The Department of Energy (DOE) national laboratory system will become more efficient as a result of actions now under way:
  - improvements in oversight, leading to a decrease in support personnel responsible for meeting oversight requirements;
  - laboratory efforts to improve productivity; and
  - increased integration of complementary capabilities across the system.
- Cost-effective, efficient operation and resource management will be major factors in evaluations of national laboratory performance and in decisions about program assignments and contractor selection.
- ORNL will remain a DOE-owned, contractor-operated multiprogram national laboratory, and DOE will remain ORNL's primary sponsor. ORNL will continue to play a principal role in fundamental science and energy resources and to apply special capabilities to support DOE needs in environmental quality and national security. Work for other sponsors, consistent with the Laboratory's mission assignments, will provide a means of leveraging scarce resources.
- Partnerships with universities, industry, and state and regional organizations will provide an increasingly important means of making the Laboratory's capabilities available to others in the national interest.

- Effective program development, resource planning, and marketing, carried out in collaboration with a variety of partners (local, state, national, and international), will provide opportunities to pursue new technical directions.

3.3 • Strategic Goals and Objectives

ORNL has established six strategic goals, each with three objectives, to move the Laboratory toward its vision. Linkages between these goals and the science themes and critical questions identified by DOE's Office of Science (DOE-SC) are shown in Table 3.1.

- **Deliver new insights into the nature of materials and energy through world-class programs in neutron science and nuclear physics.**
  - Secure the world's best capabilities for neutron science and technology and apply them to biotechnological, materials, and basic research problems.
  - Maintain world leadership in the use of radioactive ion beams to broaden the understanding of nuclear structure, nuclear astrophysics, and nuclei subjected to extreme temperatures and pressures.
  - Broaden the use of ORNL's existing neutron sources and accelerators by outside partners.
- **Integrate a fundamental understanding of biological and environmental systems with computational and technological expertise to advance human health and sustainable development.**
  - Enhance ORNL's capabilities in functional genomics and apply them to the development of practical applications in medicine, agriculture, energy production, environmental protection, and industrial processes.
  - Deepen the understanding of environmental processes and systems and generate innovative technology solutions to energy-related environmental problems.
  - Integrate and extend capabilities in separations science, isotope production, and biotechnology to provide new processes and techniques for nuclear medicine, waste management and environmental restoration, and national security.
- **Create and apply knowledge about materials through research aimed at developing and engineering materials properties.**
  - Advance fundamental understanding of materials through interdisciplinary research.
  - Develop advanced materials technologies that provide innovative solutions to national priorities in energy, national security, and the environment.
  - Enhance partnerships in materials science R&D.

Table 3.1
Linkages between ORNL strategic goals and DOE-SC science themes and questions

DOE-SC themes and questions	ORNL strategic goals: New insights from neutron science and nuclear physics	Advances in human health and sustainable development	Development and engineering of materials	Knowledge and technologies for energy production, delivery, and use	Computational resources, tools, and techniques	New knowledge in measurement and analytical sciences
Fueling the Future						
Clean new energy sources		◆		◆	◆	◆
Efficient, environmentally sound energy systems	◆	◆	◆	◆	◆	◆
Protecting Our Living Planet						
Sources and fate of energy-related by-products		◆		◆	◆	◆
Response of complex biological and environmental systems to energy use		◆	◆	◆	◆	◆
Factors that change global climate and their control		◆		◆	◆	
Exploring Energy and Matter						
Fundamental components of matter	◆					
Origin and fate of universe	◆					
Complex, dynamic systems	◆	◆	◆	◆	◆	◆
Extraordinary Tools						
Exploring the frontiers of the natural sciences	◆	◆				◆
Predicting the behavior of complex systems					◆	
Increased capacity for multidisciplinary science	◆	◆	◆	◆	◆	◆

- **Provide scientific knowledge, advanced technologies, and assessments that support the production, delivery, and use of reliable, economical energy with minimal adverse environmental impacts.**
  - Provide advanced technologies and materials for biomass, fission, fossil, and fusion energy sources.
  - Develop efficiency improvements in the delivery and use of energy for buildings, manufacturing, and transportation.
  - Improve analytical methods for exploring the effects of human activities on the environment.
- **Develop and apply state-of-the-art computational resources, tools, and techniques to meet new scientific and technical challenges.**
  - Extend ORNL's high-performance computing, data storage, and networking environment, in a balanced way, to attack a new generation of problems.
  - Enhance ORNL's leadership in systems and strategies for high-performance distributed computing, including expanding partnerships.
  - Sustain ORNL's leadership in computational tools and techniques for highly parallel, and geographically distributed, environments.
- **Create new knowledge in measurement and analytical sciences and apply it to the design and implementation of methods for detecting, measuring, monitoring, and controlling phenomena important to basic research and technological applications.**
  - Advance the state of the art in photonics, electronics, signal processing, sensor development, and simulation and integrate these capabilities to provide unique measurement and control systems.
  - Advance the state of the art in analytical chemistry, analytical separations, and chemical physics as a basis for novel prototype methods and instrumentation to achieve sensitivity, selectivity, and field practicality.
  - Advance the state of the art in nuclear detection systems for dosimetry, criticality safety assessment, diagnostics, nuclear reactor and nuclear material monitoring, nuclear physics experiments, and nuclear material characterization.

3.4 • Strategic Directions

ORNL will advance toward its strategic goals by

- pursuing the major initiatives presented in Sect. 4,
- addressing critical science questions,
- sustaining capabilities that are essential to its ability to conduct leading-edge R&D for DOE and other sponsors, and
- applying its capabilities to meet national needs, consistent with its mission assignments.

3.4.1 • Pursuing Major Initiatives

ORNL's major initiatives in neutron science, functional genomics, and distributed computing are described in Sect. 4. These initiatives are keys to the accomplishment of ORNL's strategic goals, and they will enhance ORNL's ability to support DOE in carrying out its missions in science and technology, energy resources, environmental quality, and national security.

3.4.2 • Answering Critical Questions

3.4.2.1 • Nuclear Physics with Radioactive Ion Beams

An advanced isotope separator on-line (ISOL) facility for the production of accelerated beams of radioactive isotopes was identified in the 1996 Long-Range Plan for U.S. Nuclear Science, prepared by the DOE/National Science Foundation (NSF) Nuclear Science Advisory Committee (NSAC), as the next major facility to be constructed for U.S. nuclear science. A unique opportunity exists for the construction of such a facility at ORNL.

First-generation ISOL facilities based on existing accelerators and reactors are being constructed and operated in North America, Europe, and Japan. For example, the Holifield Radioactive Ion Beam Facility (HRIBF) at ORNL is the first such ISOL facility that can address a wide range of both nuclear structure and nuclear astrophysics topics.

The advanced ISOL facility proposed in the NSAC Long-Range Plan will provide the larger variety of more intense radioactive ion beams (RIBs) needed to take full advantage of the scientific opportunities in this new interdisciplinary research field. Topics to be studied include

- the limits of nuclear stability and the evolution of nuclear shell structure, interactions, and collective modes at the limits of nuclear stability;
- production of new heavy and superheavy nuclei;
- exotic transfers of nuclear matter;
- mechanisms of nucleosynthesis, stellar explosions, and galactic chemical evolution;
- new tests of fundamental symmetries; and
- tribological and biological studies associated with the implantation of radioactive nuclear species.

With the expertise derived from building and operating the HRIBF, which can be considered a prototype for the advanced ISOL facility, ORNL is the logical institution for this facility, which has an estimated cost of $150 million to $200 million. Furthermore, the scientific program of such a facility is consistent with the traditional interests of the ORNL Physics Division staff and the users of the HRIBF.

Physics Division staff members have been working for several years to demonstrate the advantages of locating an advanced ISOL facility at ORNL. The *ORNL Institutional Plan for FY 1998–FY 2002* (ORNL/PPA-97/2, January 1998) presented a possible layout for the new facility at the HRIBF site. DOE's plans to construct the Spallation Neutron Source (SNS) at ORNL (see Sect. 4.1.1) have provided the Laboratory with a much-enhanced opportunity.

The most effective methods now known for producing radioactive ions are reactions induced by high-energy protons. The SNS uses a very high intensity beam of high-energy protons. The initial performance requirements of the SNS call for a linear accelerator (linac) that produces 1 mA of 1-GeV protons, upgradable at a later date to "significantly higher

power." The availability of this device offers a tremendous opportunity to propose an extremely cost-effective RIB facility. A small fraction of the 1-GeV proton beam would be extracted at the end of the SNS linac and delivered to the RIB production target of the advanced ISOL facility. After diffusion from the target, the radioactive atoms would be ionized and mass-selected. A high-resolution mass separator would select a single isobar for acceleration in a heavy ion linac. After acceleration, the beams of radioactive ions could be directed to any of a wide variety of highly specialized experimental stations. An architect's view of the advanced ISOL facility constructed in conjunction with the SNS is shown in Fig. 3.1.

The concept of an advanced ISOL facility at ORNL is being finalized. The availability of a 1-GeV proton beam from the SNS linac means that the construction funding for the advanced ISOL facility can be concentrated on the RIB production and radiation handling areas and on the heavy ion accelerator system, thus providing an extremely versatile facility for research with RIBs. This second-generation ISOL facility will be capable of providing a broad range of intense proton- and neutron-rich beams of radioactive ions to a large scientific user community. The facility will produce intense beams of most neutron-rich fission fragments with half-lives greater than about a second and with sufficient volatility to diffuse from a hot target. Intense beams of these isotopes are not available from first-generation ISOL facilities, such as the HRIBF. In addition, the advanced ISOL facility will provide a larger variety of proton-rich RIBs than the HRIBF. Both proton- and neutron-rich RIBs will be accelerated from energies of tens of kiloelectron volts for materials science, nuclear mass measurement, and radioactive target preparation to energies near and above the Coulomb barrier for studies of nuclear structure and nuclear astrophysics.

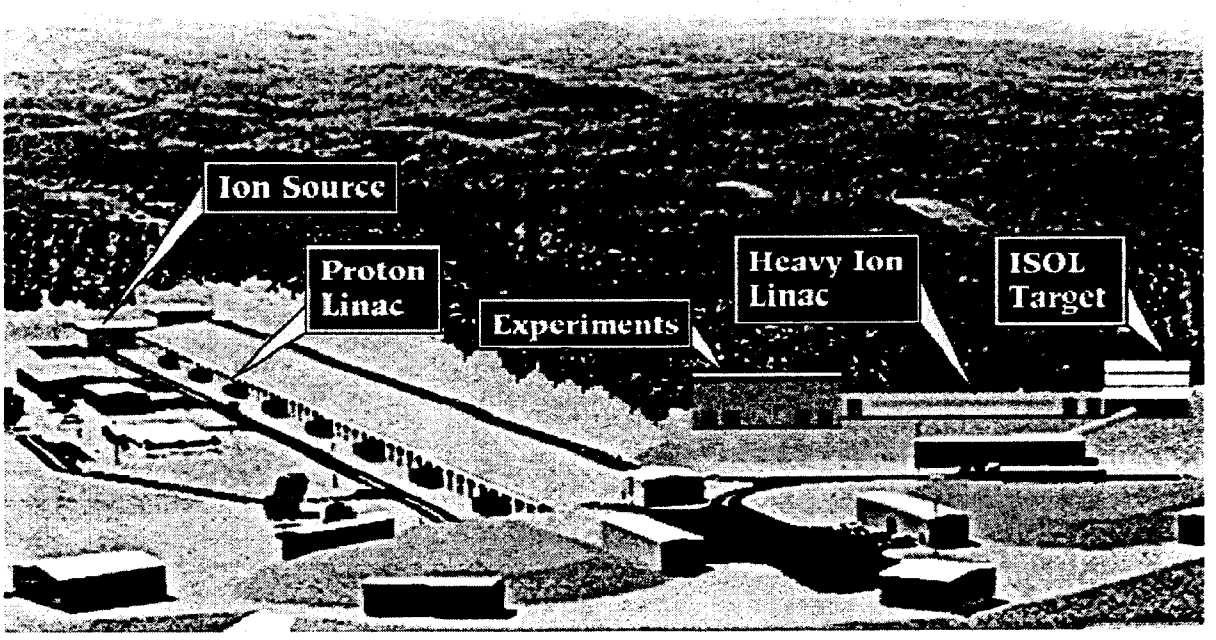


Figure 3.1
Possible layout for an advanced ISOL facility at the Spallation Neutron Source.

3.4.2.2 • Advanced Materials Characterization

As the complexity of materials and the requirements on their performance have increased, demands for detailed descriptions of the interactions among structure, composition, and properties of materials have soared. Major probes for characterizing materials include neutrons, X rays (or light), and electrons (and related techniques). To answer critical questions about the nature of matter and to develop the advanced materials needed for more efficient energy systems, DOE must maintain cutting-edge characterization tools in each of these areas.

For neutron science, this need will be met by the SNS and the upgrades to the High Flux Isotope Reactor (HFIR) and associated neutron scattering facilities. The need for advanced X-ray characterization tools is being addressed by ORNL beam lines at Argonne National Laboratory's Advanced Photon Source. Investments to meet future needs for electron characterization and related techniques, however, are lagging those in the other areas.

As a leader in the development of techniques and instrumentation for analysis of materials at the atomic level, ORNL has one of the nation's strongest and broadest materials sciences programs. This area is the focus of collaborative research with universities and industries across the United States. Characterization of materials at ORNL user facilities is a major component of many of these collaborations.

Appropriate housing for the Laboratory's advanced analytical electron microscopes, atom probe field ion microscopes, and similar instrumentation is a high-priority near-term requirement. This equipment is now scattered across the ORNL campus in buildings that barely meet the manufacturers' requirements for optimum operation. These buildings will not allow ORNL to maintain state-of-the-art instrumentation for the next generation of this equipment.

ORNL proposes to construct an Advanced Materials characterization Laboratory (AMCL) to address this issue. A new structure with 3,000 m^2 (32,000 ft^2) of space, the AMCL will provide the high-quality environment required to optimize the performance of sophisticated characterization equipment essential for the next generation of advanced materials R&D. It will foster state-of-the-art materials characterization that is essential for understanding materials and materials-related processes and phenomena that underpin energy technologies and industrial endeavors.

Ideally, this facility will house equipment funded by several DOE offices, primarily DOE-SC and the Office of Energy Efficiency and Renewable Energy (DOE-EE). Two of ORNL's major user programs—the High Temperature Materials Laboratory, funded by DOE-EE, and the Shared Research Equipment Program, funded by DOE-SC—include a strong emphasis on electron-beam characterization and related techniques. The user base for these facilities includes a strong industrial component, as well as international academic users. The management challenge will be to identify funding to construct the facility that builds on the diversity of the programmatic and user support.

Construction of the facility will be guided by the underlying principles of safety, environmental consciousness, and quality engineering, 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. Design is proposed to begin in FY 2002, with construction to be completed in FY 2004.

3.4.2.3 • Large-Scale Environmental Process Research

Environmental processes are active and variable at temporal scales from nanoseconds to millennia and at spatial scales from single molecules to the globe. In examining how complex environmental systems respond to energy use, researchers apply interpretations and assessments based on their understanding of these processes.

An enhanced program of research is needed to improve the understanding of large-scale (regional, continental, global) environmental processes. This improved understanding will aid researchers in quantifying how the environment works and in addressing such challenges as sustainably managing resources, adapting to climate change, and predicting the impacts of changes in air, water, or soil quality.

Process-level studies reveal how natural systems function and are critical to understanding the dynamics and response of ecosystems in a changing environment. Environmental processes, however, are typically studied in isolation. Rarely have interactions between these processes, or between processes and the many stressors that influence them, been studied or quantitatively characterized. The prediction of an outcome that results from several interacting factors (e.g., tropospheric ozone, global warming, changing precipitation patterns, elevated carbon dioxide, and high nitrogen or trace metal loading) is a major challenge in environmental science today.

Another complication is introduced by the fact that, for example, mature forests do not respond to changes in the environment in the same manner as collections of seedlings or small trees (as demonstrated through ORNL research). Modeling approaches for extrapolating from small-scale experiments to ecosystem, landscape, or regional scales must be verified and validated through in situ experimental manipulation of larger scale environments.

ORNL researchers have pioneered advances in methodology and approaches to the study of events that define physical, chemical, or biological change in the environment. They have also established approaches to studying natural ecosystems on a large scale, making use of the extensive resources for long-term environmental process research afforded by the Oak Ridge Reservation, a substantial portion (22,500 acres) of which has been designated as the Oak Ridge National Environmental Research Park, a DOE user facility.

ORNL plans to integrate this combination of resources and expertise with its leading-edge capabilities for measurement, modeling, and monitoring of the environment to define and create new approaches to ecosystem process research. Leveraging and enhancing current assets in large-scale ecosystem manipulation, integrated data management, ecological modeling, measurement science and sensor development, and computational science will contribute directly to the ORNL strategic objective of deepening the understanding of environmental processes and systems. This effort directly supports Office of Biological and Environmental Research (OBER) plans, outlined in the Facilities Roadmap Initiative, for integrated user facilities for experimental field research. It also supports DOE goals and objectives in science and technology and addresses the DOE-SC science theme "Protecting Our Living Planet," with specific application to critical questions about energy by-products and climate change.

The well-developed DOE and ORNL investments in scientific infrastructure at the Oak Ridge National Environmental Research Park represent a concentration of resources that is unique among U.S. ecological research centers in the United States. The park is home to major large-scale ecosystem manipulation experiments such as a Free Air Carbon Dioxide Exposure (FACE) facility; the Throughfall Displacement Experiment (TDE), aimed at understanding the impacts of climate change; and lysimeters for study of genetically engineered microorganisms. The park—particularly the Walker Branch Watershed area—is one of the

nation's most intensively studied sites for understanding biogeochemical cycling in a forested ecosystem. Overall, the National Environmental Research Park provides a combination of heterogeneous and well-characterized geology and hydrology, ecological diversity, fundamental ecosystem process research, modeling, a long-term data record, historical records of land use change, and dynamic pressures on ecosystems resulting from its suburban/industrial setting. The physiography of this ridge and valley setting provides a unique opportunity for several "replicate" catchments on contrasting soil types, further contributing to the value of the site for large-scale experiments.

This activity will enhance the role of the Oak Ridge National Environmental Research Park as a national user facility for research on large-scale environmental processes. It will provide opportunities to build on existing capabilities through new partnerships with other national laboratories, other federal agencies, and universities, allowing DOE to maximize the cost-effectiveness of the federal investment in this infrastructure.

Innovations in measurement science and technology will be applied to large-scale ecosystem manipulations to speed the development of the next generation of sensors and environmental monitoring instrumentation and the application of new nuclear and radiochemical tracer and biomarker techniques. Development of advanced methods for measurement of environmental processes will lead to expanded opportunities for cooperative R&D agreements and other forms of partnership with the environmental monitoring industry. ORNL strengths in information and data management will support the transfer of data from on-line sensors to other institutions worldwide through the Internet, making the facilities similar in concept to the DOE "virtual laboratory."

This activity will integrate focused interdisciplinary process research with other experimental, observational, and modeling studies related to ecosystem function and response. It is aligned with the findings of a review of the research needed to support an improved understanding of the impacts of global change on forest ecosystems, conducted at OBER's request and documented in *Terrestrial Ecosystem Responses to Global Change: A Research Strategy* (ORNL/TM-1998/27, September 1998). This report calls for a fundamental shift in the scale and integration of ecosystem research: from the current small-scale, single- or two-factor experiments in simple natural or artificial ecosystems to highly coordinated, large-scale, replicated experiments in complicated ecosystems, with many interacting factors evaluated at two or more levels of spatial scale and process resolution. Such experiments will require an unprecedented long-term funding commitment and large-scale experimental research at a few major sites.

In FY 1999, detailed estimates of construction and capital equipment funds needed to develop initial facilities at ORNL will be prepared. Table 3.2 represents a first approximation of projected funding requirements. OBER is the core sponsor of this activity; complementary funding is being sought from programs within DOE's Office of Energy Efficiency and Renewable Energy (DOE-EE) and Office of Environmental Management (DOE-EM) and through new collaborative partnerships with other federal agency sponsors, including the U.S. Forest Service, the Environmental Protection Agency (EPA), the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration, and the Tennessee Valley Authority.

Enhanced university interactions are being fostered through the use of these unique facilities as part of the ORNL National Environmental Research Park User Facility. For example, university investigators have secured independent funding from programs such as the DOE National Institute for Global Environmental Change to conduct research in

conjunction with the Oak Ridge large-scale environmental process experiments. University and federal agency interactions are also being developed through participation in a university-based multiagency Cooperative Ecosystem Study Unit involving the University of Tennessee, Florida A&M University, the U.S. Forest Service, the U.S. Geological Survey, and the EPA. Current interactions with the DOE-EE Industries of the Future program may be expanded through field demonstration projects related to forest products industry interests in short-rotation woody crops.

Table 3.2
Funding projections for large-scale environmental process research by fiscal year
($ in millions—BA)

	1998	1999	2000	2001	2002	2003
Operating	2.0	3.0	5.0	7.0	8.0	8.0
Capital	0.4	0.4	0.5	1.0	1.5	0.5
Construction	1.0	0.5	20.0	10.0	5.0	3.0
Total	**3.4**	**3.9**	**25.5**	**18.0**	**14.5**	**11.5**

3.4.2.4 • Clean Power Generation

The federal government has a substantial investment in energy R&D, designed to support broad national goals in energy security and environmental quality. These R&D programs represent a notable resource for the development of strategies and technologies for mitigating climate change. These strategies and technologies will also support positive economic outcomes in areas such as sustainable resources, environmental protection and remediation, population growth, and utility restructuring.

ORNL plans an effort to map technology needs for clean power production. This effort will support the development of an organized structure for the R&D necessary to attain the goals set forth in the Comprehensive National Energy Strategy and in the DOE strategic plan. It will then shift to assisting with the implementation of this structure.

The development and use of technologies for clean power generation will include a diverse group of stakeholders: federal government agencies such as the Nuclear Regulatory Commission, the Federal Energy Regulatory Commission, EPA, and DOE; states; universities; and industry participants such as utilities, independent power plants, municipalities, self-generators, suppliers, and equipment manufacturers.

Major R&D performers—the DOE national laboratories, the NSF, other government research institutions, universities, and industries—will play a major role in technology development and in strategic alignment of research efforts with technology road maps. Other organizations may include environmental groups, consumer groups, and various technical and management associations.

Producing the technologies needed for implementation of clean power will require R&D on the fuel forms, conversion systems and materials, efficiency and recovery systems, end use, and process waste streams associated with each power system. Ideally, the primary goal is to develop technology that supports a sustainable energy future while addressing global environmental concerns. Technological areas of emphasis are renewable energy, highly efficient power generation, carbon sequestration, and power distribution. (Clean

transportation systems are excluded from this effort because they will be addressed through other programs.) Funding projections are given in Table 3.3.

Table 3.3
Funding projections for clean power generation by fiscal year
($ in millions—BA)

	1999	2000	2001	2002	2003
Funding source					
DOE	1.0	2.0	4.0	8.0	12.0
Other agencies	0.1	0.2	0.5	1.0	2.0
Industry	0.2	0.4	0.8	1.5	3.0
Total	**1.3**	**2.6**	**5.3**	**10.5**	**17.0**

3.4.2.5 • Global Climate Science and Technology

Global environmental issues are 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, resource depletion, the spread of pollution, and deforestation and desertification. ORNL's Center for Global Environmental Studies (CGES) provides an interdisciplinary base for exploring these issues through a diverse program tied to the U.S. Global Climate Research Program. Work coordinated by the CGES is aimed at (1) improving the understanding of the global-scale processes of atmospheric, terrestrial, and aquatic environments; (2) developing capabilities for anticipating the long-term, large-scale effects of human actions on the biosphere; and (3) identifying options for technological and societal responses.

ORNL proposes to support the White House Initiative on Global Climate Change with an integrated program, coordinated by the CGES, that brings together the Laboratory's extensive resources in environmental research, technology development, and integrated assessment.

The White House Initiative on Global Climate Change, launched in October 1997, describes global climate change as "the premier environmental challenge and opportunity of the 21st century." The program of action proposed to address this challenge includes a major federal R&D program to spur energy efficiency and the development of lower-carbon energy sources; development of sensible efficiency standards; reductions in greenhouse gas emissions from federal sources; and regular scientific and economic reviews to ensure that policy-makers have the best possible information on climate change.

DOE will play a major role in addressing this challenge. DOE programs in global change research, development of climate-friendly energy technologies, and assessment of the impacts of energy production and use provide the basis both for understanding the potential impacts of global climate change and for developing appropriate technologies and policies to mitigate its impact.

ORNL expects to be a key resource for DOE and the nation in the development of global science and technology. ORNL's strengths in understanding both the potential impacts of global climate change and the technology options available to mitigate greenhouse gas emissions are complemented by expertise in information management and in the integration of scientific, engineering, environmental, economic, and social science expertise, which will be important in policy development.

ORNL proposes a broad program in global climate change science and technology to assist DOE in determining appropriate responses to national climate change issues. This program will build on ORNL's existing—and extensive—capabilities and programs in global change research and energy efficiency technology development, which draw on the expertise of multidisciplinary teams and public-private partnerships to tackle large, complex problems. The ORNL Global Science and Technology Program will include the following new or expanded tasks.

National Technology Portfolio

ORNL will continue the development of a national technology portfolio for reducing greenhouse gas emissions. *Technology Opportunities for the Reduction of Greenhouse Gas Emissions,* the report of a study co-led by ORNL, in collaboration with 10 other national laboratories, catalogs 47 technology pathways with significant potential for reducing greenhouse gas emissions. ORNL also co-led a multilaboratory effort, documented in *Scenarios of U. S. Carbon Reductions,* to analyze the potential impacts of energy technologies in 2010 and beyond. Other studies by DOE (e.g., on carbon management), the President's Council of Advisors on Science and Technology, and other organizations and the carbon sequestration road map now being developed by DOE provide further information that can be incorporated into assessments of technology cost and performance; these in turn will provide a basis for selecting and deploying technology.

ORNL will apply its expertise in research, technology development, and crosscutting technologies to enhance or develop greenhouse gas reduction technology pathways. This effort includes the following initiatives and projects.

- Plant biosciences. Possibilities for developing new carbon-neutral fuels and for affecting the natural flux of carbon and its storage in natural ecosystems will be addressed by a public-private Phytocarbon Research Strategy that will study carbon management using plant systems (terrestrial ecosystems, including soils; algal systems; and terrestrial biomass crops) to mitigate increases in greenhouse gases. The Phytocarbon Research Strategy will develop, apply, and deploy crosscutting research, tools, and technologies to examine carbon fluxes, carbon storage mechanisms and capacities, and carbon management strategies in plant systems on local to global scales.
- Materials. Improvements in materials used in systems that produce, store, and use energy can improve system efficiencies, extend component lifetimes, and increase performance or capacity, reducing the production of waste and greenhouse gases. ORNL's basic and applied research in materials synthesis and processing will seek new ways of producing materials and enable the creation of new materials for energy systems.
- Chemical sciences. ORNL will pursue reductions in greenhouse gas emissions through advances in chemical sciences, which are central to the design and synthesis of many materials and to the conversion of energy into heat, work, and light. In particular, ORNL will evaluate opportunities for improving processes used to purify raw materials, separate by-products, and remove contaminants to support U.S. industry in its efforts to meet greenhouse gas reduction targets. The proposed Center for Separations and Chemical Processing (see Sect. 3.4.3.3) will be part of this effort.
- Carbon management and sequestration. The use of fossil fuels to meet most of the nation's energy needs will continue into the next century. The 11-laboratory study suggests that advances in carbon sequestration technologies and novel fuel switching will be

needed after 2020 to mitigate CO_2 emissions from fossil fuel sources. ORNL's Fossil Energy Program will explore fuel decarbonization technologies to create carbon-free (i.e., hydrogen) secondary energy sources and scientific advances and technology development to sequester CO_2. One of ORNL's focus areas will be to use separation methods and processes for hydrogen-CO_2 mixtures to increase efficiencies and yields of hydrogen production methods that use carbon-containing fuels as their primary energy source. ORNL is using Laboratory Directed R&D (LDRD) funds to evaluate methods for characterizing and producing methane from methane hydrates and to address the technology, safety, and environmental issues related to methane hydrates as primary energy sources.

- Buildings. The buildings sector accounts for 36% of the nation's primary energy use and 66% of its electricity use. ORNL's comprehensive buildings technology program will examine ways to reduce electricity use, reduce the use of energy required for space and water heating and other domestic purposes, and expand the potential for on-site generation of electricity. ORNL improvements in the energy efficiency of building envelopes, equipment, and appliances and the development of intelligent building systems will yield a set of technology advances to improve the energy efficiency of homes and commercial buildings.
- Transportation. Accounting for 32% of U.S. CO_2 emissions and 26% of the nation's energy use, the transportation sector is almost totally dependent on petroleum fuel. This area presents significant opportunities and challenges for advanced technologies to reduce greenhouse gas emissions. Opportunities lie in the continuous improvement of conventional vehicle technologies, in the promise of new and revolutionary propulsion systems and alternative fuels, and in the application of information technologies to manage and integrate intermodal transport systems in innovative and more efficient ways. ORNL will focus on understanding combustion processes through simulation-based modeling (see Sect. 4.3.2.1) and will seek improvements in the performance and efficiency of internal combustion engines. Improvements in ORNL's combustion simulation capabilities are being supported by LDRD funds.
- Nuclear power. Nuclear power plants supply ≈22% of the nation's electrical energy; they also provide (and are expected to continue providing) the majority of electrical power in many other countries. ORNL's focus in nuclear energy science and technology will address three key areas: the management of materials degradation by means of advanced materials analytical and inspection technologies, the optimization of power generation, and R&D to support license renewal. Developments in these areas should yield longer lifetimes, more days of operation per year, and more power production per plant per day for existing power plants, thus preventing the substitution of fossil fuel for nuclear power and avoiding the introduction of more greenhouse gases per megawatt of power produced.
- Environmental policy and technological change. Determining the policies that will be most effective in bringing about environmental sustainability is a new and critical area of research for economists and other social scientists. ORNL will work to establish a program in technology policy research, devolp a regional impacts model, and promote new initiatives in international cooperation to provide the tools needed for global climate change policy research.

Vulnerability Examination

ORNL will examine the vulnerabilities of the nation—in terms of its ecological systems, its major economic sectors, and its social infrastructure—to climate variability and change. The Laboratory will apply its expertise in assessment and global change science to participate in (and lead, as appropriate) an integrated assessment process that includes a broad community of researchers and stakeholders. The process will consider the nation's vulnerabilities in the context of other important environmental stresses and concerns, taking into account differences between and common themes among regions (Southeast, Heartland, Pacific Northwest, etc.).

As this national activity develops and moves toward the first assessment in FY 1999, ORNL will seek leadership roles in a number of regional and national activities. ORNL's past experience and current capabilities will benefit regional assessments and national integration activities. Areas of concentration in FY 1999 include the following.

- Development, coordination, and distribution of information on (1) global change and variability and (2) long- and short-term trends in the economy, industry, ecosystems, water resources, food and agriculture, etc. A national perspective on these sectors must be combined with the regional specificity required to assess global change and variability. ORNL can play an important role by coordinating a national effort that brings together expertise from academia, industry, and the national laboratories to develop national and regional backgrounds and scenarios. The development of a prototype regional climate center at ORNL (see Sect. 4.3.2.1) is expected to lead to significant improvements in the availability and distribution of data and information on climate variability and change as predicted by global and regional models.
- Support for the national synthesis team and faciliation of interregional coordination. ORNL is assisting in setting national and regional assessment goals and priorities and in ensuring oversight of the national assessment process.

Supporting these activities will be continuing efforts to examine (1) the effects of climate on ecological systems (e.g., with the Free Air CO_2 Enrichment facility, the Walker Branch throughfall displacement experiments, and new experiments addressing the effects of multiple climate variables acting together), (2) conflicts in use of natural resources (e.g., water resources, agriculture, forest), and (3) the influence of climate change and variability on the economy, urban centers, and other socioeconomic issues, as described in Sect. 3.4.2.3.

Technology Strategy Formulation

ORNL will integrate the results of its portfolio development and the vulnerability examination to provide the basis for formulation of a national climate change technology strategy that incorporates an aggressive program of R&D, demonstration, and deployment for energy efficiency, clean energy, and carbon sequestration technologies that meet cost and performance requirements.

These efforts will be linked to ORNL's existing and planned programs in computational science; integrated data management; ecological modeling; large-scale ecosystem manipulation; large-scale environmental process research (see Sect. 3.4.2.3); measurement science and sensor development; and analysis of policy, energy, and human systems. Funding (see Table 3.4) is sought from the DOE-SC Office of Biological and Environmental Research; DOE-EE; the DOE Office of Fossil Energy (DOE-FE); and the DOE Office of Nuclear Energy, Science and Technology (DOE-NE).

Table 3.4
Funding projections for Global Climate Science and Technology by fiscal year
(in millions of dollars)

	1999	2000	2001	2002	2003
Operating					
Office of Energy Efficiency and Renewable Energy	2.0	6.0	10.0	10.0	10.0
Office of Science	0.7	4.0	6.0	8.0	8.5
Office of Fossil Energy	0.3	3.5	4.5	5.5	8.0
Office of Nuclear Energy, Science and Technology	0.1	1.0	1.0	1.0	1.0
Equipment	0.1	0.1	0.3	0.3	0.5
Total	3.2	14.6	21.8	24.8	28.0

3.4.3 • Providing Essential Capabilities

3.4.3.1 • Crystal Growth

The science of single-crystal growth, which encompasses the growth of single crystals in both bulk and thin-film form, is critical not only to DOE missions but also to the missions of many other federal agencies. Many of the basic and applied research programs supported by the DOE-SC Office of Basic Energy Sciences rely on the unique properties of single crystals, which are important in areas ranging from welding and joining to environmental sciences.

ORNL is unique in its combination of crystal-growth and materials characterization capabilities. Its single-crystal research is characterized by a history of successes that date back to the early 1950s, when metal crystals produced at ORNL were used in pioneering studies of radiation effects in solids. The present DOE commitment to crystal-growth R&D at ORNL and the unique crystal-growth capabilities of the Laboratory make ORNL the logical base on which to build a national program.

ORNL's capabilities span a wide range of techniques (Czochralski growth, submerged-arc-fusion growth, electron-beam float-zone growth, flux growth, Bridgman methods, etc.). ORNL also has unique capabilities for the growth of actinide-doped and other radioactive crystals, which are important to actinide element research and are applicable to DOE programs in fissile materials disposition.

To build on existing programs and to make its resources in this key area available to other federal agencies, ORNL proposes to establish a National Center for Crystal Growth. The Center will serve the crystal-growth R&D needs of U.S. government and university programs in the physical, chemical, engineering, and biological sciences; it will also replace capabilities lost in the downsizing of industrial R&D programs.

Programmatic elements include

- a comprehensive pure and applied research effort on oxide single-crystal growth, semiconductors, metals and alloys, proteins and other biological crystals, substrate crystals and film growth, and application of materials characterization capabilities;
- a national user program;
- an education component (undergraduate traineeships, graduate research fellowships, postdoctoral research fellowships, faculty participation contracts and travel support);
- a crystal-growth information center; and

- a national archive of well-characterized, high-quality single crystals, available to U.S. investigators through loans or on a cost-recovery basis.

Physical elements include

- a dedicated state-of-the-art laboratory building;
- modern crystal-growth equipment for every major crystal-growth method;
- a crystal-growth information system; and
- an archive of single crystals with properties keyed to a database.

ORNL will work to develop national support and funding from multiple agencies and to build a dedicated constituency among crystal-growth scientists. The center would conduct crystal-growth research and also function as a national user center for academic, industrial, and government scientists requiring support in various aspects of crystal growth.

Funding (see Table 3.5) will be sought from DOE; the Department of Defense (DOD); NASA; the NSF; and the National Institutes of Health (NIH). Support will also be solicited from companies engaged in single-crystal growth.

The development of the National Center for Crystal Growth will involve several ORNL divisions and facilities. The center will require a new laboratory building, at a cost of about $35 million. The continuing program of R&D will entail an annual operating budget of about $15 million. The center's R&D program and funding base will be supplemented by Work for Others contracts with private industry, subcontracts in support of academic and DOD research, and cooperative R&D agreements. An educational program will be developed and administered in conjunction with southeastern universities.

The center will bring users, guest scientists, and students to ORNL from throughout the United States and from other countries. The proximity of NASA's Marshall Space Flight Center and the University of Alabama Center for Microgravity Research in Huntsville, Alabama, will provide opportunities for joint programs. The National Center for Crystal Growth will directly complement the increased activities at the HFIR and the SNS, since it will represent a major focus for the preparation of single-crystal research specimens for these neutron science facilities.

ORNL will seek innovative approaches to funding for the new laboratory, with an emphasis on multiagency support. The National Center for Crystal Growth represents an opportunity for agencies such as DOE, DOD, NASA, NSF, and NIH to leverage their research funds and to provide increased opportunities for their grantees to carry out their research. As a user facility, the center will provide university, industry, and government-supported scientists with the opportunity to perform crystal-growth research using a broad range of state-of-the-art crystal-growth equipment.

Table 3.5
Projected funding for the National Center for Crystal Growth by fiscal year
($ in millions)

	1998	1999	2000	2001	2002	2003
Funding source						
DOE	0.2	1.0	5.0	4.0	3.0	3.0
Other agencies	0.2	2.0	25.0	16.0	11.0	11.0
Industry	0.0	0.5	0.5	0.5	1.0	1.0
Total	0.4	3.5	30.5	20.5	15.0	15.0

3.4.3.2 • Isotope R&D and Production

ORNL applies unique capabilities and facilities to carry out

- R&D on stable and radioactive isotopes and applications for these materials;
- development of isotope production processes and products;
- specialty production of custom isotopes and isotope products for research in medicine, nutrition, biology, geology, physics, chemistry, and environmental sciences;
- production of isotope products for crucial national needs; and
- technology transfer of isotope production processes and products to industry.

Work is done in collaboration with other national laboratories and with universities and research institutions. This work supports the DOE National Isotope Strategy and its supporting legislation. Funding is supplied by several DOE offices.

Resources are distributed across ORNL's Chemical Technology, Life Sciences, Metals and Ceramics, and Research Reactors divisions. Facilities for isotope production at ORNL include the HFIR, the Radiochemical Engineering Development Center, the calutrons of the Isotope Enrichment Facility, the Radioisotope Development Laboratory, and, potentially, the Plasma Separation Process equipment. These facilities are supported by extensive resources for handling radioactive materials.

The isotopes capability is synergistic with ORNL's strengths in neutron sciences, materials research, and separations science. It is a critical component of U.S. R&D and production activities in support of beneficial uses of isotopes. ORNL's activities in medical isotopes research and production and in ^{233}U utilization and operations demonstrate the value of this integrated capability.

Medical Isotopes Research and Production

The availability of reactor-produced, neutron-rich radioisotopes is a key element in ORNL's nuclear medicine program, which involves the design and development of tissue-specific radiopharmaceuticals for disease diagnosis and therapy. Research at ORNL provides new and improved methods for production and processing of radioisotopes for both research and clinical use. ORNL researchers conduct preclinical tests of new radiolabeled agents in animals, prepare radiopharmaceuticals, and perform imaging and characterization studies. Clinical evaluation of new ORNL agents is performed through medical cooperative programs at hospitals and universities throughout the world.

ORNL's HFIR plays an important role in providing radioisotopes both for R&D at ORNL and for sale through the Isotope Production and Distribution Program (IPDP) sponsored by DOE-NE. The recent addition of six target positions to the HFIR has expanded ORNL's capabilities for producing medical radioisotopes.

Cooperative R&D agreements support the development of new methods of using ^{188}Re and other radioisotopes to inhibit coronary artery restenosis. Phase I clinical protocols using ^{188}Re for restenosis therapy are in progress, and several companies are considering commercial development of this technology. The HFIR is also a key facility for the preparation of a variety of radioactive wire sources being developed for this application.

Phase I trials are evaluating the use of ^{188}Re agents to relieve bone pain resulting from skeletal metastases. The high flux of the HFIR is also required for another important therapeutic radioisotope, ^{117m}Sn. Phase I clinical trials of ^{117m}Sn-labeled DTPA for bone pain palliation are under way, as is commercial development. Several other HFIR-produced

medical radioisotopes are in various stages of production and processing development at ORNL and are being evaluated at various research centers through collaborative projects.

ORNL is also drawing on another resource for isotope production: its ^{233}U repository, which represents a unique source of ^{229}Th. This isotope decays to ^{225}Ac, which in turn decays to ^{213}Bi. Institutional expertise in separations science and nuclear medicine was applied to the development of methods for recovery and purification of ^{229}Th from ^{233}U, for recovery of ^{213}Bi from ^{229}Th, and (in collaboration with NIH) for attachment of ^{213}Bi to monoclonal antibodies (MAbs). The $^{225}Ac/^{213}Bi$ generator system developed and sold by ORNL is a convenient source of ^{213}Bi for treatment of micro tumors. The MAbs with ^{213}Bi have been shown to be effective in selectively destroying tumor cells in mice. In addition, ^{213}Bi has promise as a leukemia treatment. Clinical trials conducted at the Memorial Sloane-Kettering Cancer Center in New York have yielded encouraging preliminary results.

These R&D activities pave the way for new therapeutic products. A major current area of research is the development of radiolabeled receptor ligands, which target brain receptors that change in many dementias, such as Alzheimer's disease. These agents are now being evaluated in primate studies and may offer a method of evaluating functional alterations in receptors in various diseases through nuclear medicine imaging techniques.

^{233}U Utilization and Operations

ORNL operates a national repository for ^{233}U in Building 3019. Recent and planned activities in ^{233}U utilization and operations draw on ORNL's isotope R&D and production capabilities. In addition to developing techniques for recovering ^{213}Bi from ^{233}U and applying it to cancer therapy, ORNL is focusing its resources and expertise on several projects that support DOE and national needs in environmental quality and national security.

- Molten Salt Reactor Experiment (MSRE) remediation. The MSRE Remediation Project, which is recovering ^{233}U from a shutdown experimental reactor at ORNL, is conducting gas phase separations of ^{233}U as uranium hexafluoride and transferring this material as a complexed solid compound to Building 3019. Over the next several years, this material will be chemically converted to a stable oxide and packaged for long-term storage or disposition. Later, the residual molten salt fuel at the MSRE will be removed, and the ^{233}U will be separated and processed for disposition.
- Defense Nuclear Facility Safety Board (DNFSB) Recommendation 97-1. The execution of DOE's Implementation Plan for DNFSB Recommendation 97-1, "Safe Storage of Uranium-233," has accelerated the inspection, chemical stabilization, and repackaging of selected ^{233}U materials stored in Building 3019.
- Thorium nitrate stabilization. DOD stores large quantities of thorium as thorium nitrate salts in the Strategic Materials Stockpile. ORNL is providing technical assistance on the commercial stabilization of this material for long-term storage. An inventory of aqueous thorium nitrate containing a small quantity of ^{233}U, stored at Building 3019, will be processed and stabilized in a separate activity.
- Disposition planning. ORNL is the lead laboratory for DOE's Office of Fissile Materials Disposition on the definition and evaluation of strategies for the disposition of ^{233}U and minor actinides. Activities in this area are discussed in Sect. 2.3.3.4.

3.4.3.3 • Separations Science and Chemical Processing

Problems in separations and chemical processing challenge industries worldwide. Increasingly stringent requirements for purity are being placed on manufacturers of chemicals, pharmaceuticals, food, and materials. The recovery of chemicals used in industrial processes is both environmentally and economically necessary. Improvements in separations can contribute to better industrial products and efficiency and to maintaining the competitiveness of U.S. industry. Workable designs for new processes depend on accurate design and pilot plant data; the availability of good data also minimizes engineered overcompensation and ensures more efficient use of resources and energy.

Many of these problems and challenges for process industries are also concerns across the DOE laboratory system. The increasing importance of this area is illustrated by the formation, during the last decade, of new divisions, devoted to separations, of the American Institute of Chemical Engineers and the American Chemical Society.

Oak Ridge expertise in separations and chemical processing was initially developed in response to the challenge of purifying crude uranium and separating isotopes. Work based on separations and chemical processing has continued throughout the Laboratory's history, drawing on expertise in solvent extraction, inorganic membranes, adsorption, ion exchange, field-enhanced separations, and dilute solution chemistry. ORNL's chemical processing capabilities 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.

With the most comprehensive capabilities in separations within the DOE system, ORNL carries out programs ranging from fundamental research to demonstration projects, supporting programs in DOE-SC, DOE-NE, DOE-EM, DOE-EE, and DOE-FE. ORNL divisions involved include the Chemical Technology, Chemical and Analytical Sciences, Engineering Technology, Environmental Sciences, Instrumentation and Controls, and Robotics and Process Systems divisions. Industrial, academic, and government interest in ORNL separations capabilities is evidenced by joint research projects and cooperative R&D agreements in areas such as field-enhanced separations, thermophysical measurements, membrane separations of refinery gases, ultrapurification of water, computational chemistry and chemical engineering, and life-cycle analysis.

A survey of potential industrial users shows strong interest in and support for a national laboratory center with separations and chemical processing capabilities. This interest results in part from the streamlining and reengineering 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 shows that firms are beginning to plan for obtaining the needed services.

ORNL proposes to capitalize on its assets and on the interest exhibited by the industry by establishing an initiative in separations science and chemical processing. As part of this initiative, ORNL proposes to develop a center to coordinate its separations and chemical processing capabilities, establish collaborations with academia, and extend the capabilities to the industrial sector. The Center for Separations and Chemical Processing (CSCP) will provide an integrated program and a user center to support the U.S. chemical industry.

The CSCP will draw on the capabilities of several ORNL divisions:

- The Chemical Technology Division has wide expertise in separation processes and chemical processing in general, including work with nuclear materials, waste and environmental materials, and biological products.
- The Chemical and Analytical Sciences Division has strong capabilities in studying the chemistry of separation methods, including the development of separating agents, and in providing important innovative analytical chemistry methods and services.
- The Metals and Ceramics Division has experience and capabilities in inorganic filters for high-temperature gas separations.
- The Instrumentation and Controls Division has extensive capabilities in measurement and control needed for separations R&D and for industrial operations.
- The Environmental Sciences Division is active in soil washing and other environmental separations.
- The Robotics and Process Systems Division has expertise in remotely operated separations processes.
- The Engineering Technology Division has experience in several forms of physical separations.

The CSCP will also draw on advanced inorganic membrane technology efforts, now managed by Bechtel Jacobs Company, which are directed toward commercial applications to gas/gas, solid/ gas, and liquid/liquid separations.

The CSCP will build on existing ORNL efforts in separations and coordinate expansion of these efforts by facilitating participation in new programs proposed by DOE and by industrial firms or consortia. Opportunities include the expansion or redirection of a program for measuring the physical properties of hydrocarbons and other materials important to separations in the petroleum and petrochemical industries, a new effort to solve waste problems for DOE-FE, and other activities such as the DOE-EE Industries of the Future initiative.

The CSCP will also establish a user center for separations and related topics. The first step in establishing the user center is the addition of new capabilities and staff to measure chemical and physical properties. This effort will have the added benefit of expanding ORNL's involvement in related computational research on chemical and physical properties. Staff members who are highly regarded and actively consulted by the petroleum industry will be sought, and the CSCP will serve to create a wider audience for their capabilities.

The CSCP will be expanded as resources allow to include facilities for testing separation processes on both laboratory and pilot scales, building on available equipment at ORNL (test loops and test stands) for testing processes, equipment, and instrumentation. These facilities will be available to government, university, and industrial users and will also provide a platform for testing instrumentation and computer analyses of separation systems.

Through these activities, the CSCP will provide integration of diverse capabilities and create a complete and accessible separations competency. The CSCP will maintain a DOE identity, with initial work expected to come from DOE in the form of a new environmental project on produced water mitigation from DOE-FE. Subsequent initiatives will focus first on DOE-EE and then on encouraging industrial participation and support, both through industry use of ORNL capabilities to perform R&D and through use of ORNL user facilities by individual companies to perform selected separations/processing R&D. The availability of ORNL's facilities, the CSCP focus on industrial interactions, and the closing of many industrial laboratories should combine to foster success in these efforts.

ORNL will take the lead in the CSCP; fruitful cooperation is expected with industries, universities, and other DOE laboratories. Efforts to establish working agreements in separations with the University of Tennessee and the University of Texas are continuing.

To be complete, the CSCP will require additional equipment and, eventually, a new building. The equipment will be acquired on an incremental basis, but significant capital equipment will be required from time to time. A new building for the CSCP will be needed in the future; it will be incorporated in ORNL's plans for future site development. Projected funding is summarized in Table 3.6. Resources are sought from DOE-SC (Basic Energy Sciences—KC); DOE-EE (Industrial Energy Conservation—ED); and DOE-FE (Petroleum—AC). Support will also be requested from DOE-NE (Nuclear Energy R&D—AF, Isotope Production and Distribution—ST) and DOE-EM (EM30, EM50) and from industry sponsors.

Table 3.6
Funding projections for Separations and Chemical Processing initiative by fiscal year
(in millions of dollars)

	1999	2000	2001	2002	2003
Funding source					
DOE					
Office of Fossil Energy	0.50	1.6	2.0	2.0	2.0
Office of Energy Efficiency and Renewable Energy	0.10	0.4	0.6	1.0	1.5
Office of Science	0.05	0.2	0.3	0.3	0.4
Industry	0.20	0.6	1.0	1.5	2.0
Department of Defense	0.00	0.4	0.6	0.6	0.6
Total	**0.85**	**3.2**	**4.5**	**5.4**	**6.5**

3.4.3.4 • Robotics and Intelligent Machines

The DOE national laboratory/production plant complex has been a leader in the basic research, development, and application of robotics and remote systems since the mid-1940s. Many of the laboratories and test facilities used for this work are unique national resources that are critical to the accomplishment of DOE's missions in science and technology, energy resources, environmental quality, and national security. DOE Under Secretary Ernest Moniz recently chartered a team to prepare a DOE agency-wide road map for future work on robotics and intelligent machine. Under Secretary Moniz requested that this team examine robotics and intelligent machines as a critical enabling technology, with the objective of developing a crosscutting technology pull strategy for the next 20 years.

The road map is being prepared by a multidisciplinary team that includes representatives from each of the DOE Program Secretarial Officers (PSOs) with mission needs requiring robotics and intelligent machines. The PSO representatives are defining the principal programmatic needs, which provide the application pull for robotics and intelligent machines in the DOE programmatic missions. The technology needs are being defined by the key participating laboratories: Sandia National Laboratories, Idaho National Engineering and Environmental Laboratory, and Oak Ridge National Laboratory. The strategic vision of this team is to revolutionize DOE's:

- manufacturing processes,
- remote handling processes, and
- monitoring and surveillance processes.

Key goals include reducing and/or eliminating DOE worker hazard exposure, improving quality and cost-effectiveness in missions, enabling programmatic missions not presently possible, and improving access to scientific user facilities.

The time frame for the strategic vision and the Robotics and Intelligent Machines Enabling Technology Road Map is FY 1999–FY 2020. The first version of this Enabling Technology Road Map was reported to Under Secretary Moniz in June 1998, with updates planned for the full 20-year term of the initiative.

ORNL expects to continue its support of DOE mission needs in robotics and intelligent machines. ORNL performs R&D, demonstration, and application of remote systems, robotics, teleoperation, and related aspects of intelligent machines through interdisciplinary programs for DOE, DOD, and other sponsors. Much of this work is conducted at the Center for Engineering Systems Advanced Research. ORNL also works with other DOE facilities to develop and apply advanced robotics technology to address needs in energy exploration, environmental restoration, defense, transportation, and other areas. For example, the disposal of unexploded ordnance (see Sect. 3.4.4.3) will draw on ORNL robotics and remote systems capabilities.

3.4.4 • Meeting National Needs

3.4.4.1 • Biotechnology

ORNL's diversity of interactive disciplinary foundations and its distinctive capabilities in biological and environmental sciences and technology place it in a unique position in the emerging field of biotechnology, which is addressing DOE and national needs in health and environmental protection, biomedical applications, environmental remediation, pollution abatement, and energy production. The ORNL Center for Biotechnology provides a means for integrating activities and forming partnerships with other institutions; it is ORNL's link to the Biotechnology Interlaboratory Council, through which the national laboratories are developing interorganization collaborations and working toward the development of a DOE Virtual Biotechnology Laboratory.

The Center for Biotechnology integrates activities across 14 ORNL divisions and forms partnerships with other institutions, both public and private, throughout the world. DOE sponsors include DOE-SC, DOE-DP, DOE-EE, DOE-EM, DOE-FE, and the DOE Office of Nonproliferation and National Security (DOE-NN). Other Federal agencies sponsoring biotechnology R&D at ORNL include DOD (all branches, including the National Guard), EPA, NIH, and NSF. Cooperative R&D agreements to extend ORNL expertise to industry are also in place and are expanding. Research activities extend from the Arctic Ocean to Antarctica and include biomedical sciences, the Human Genome Program, the development of systems for producing biofuels and chemicals from renewable feedstocks, and the bioremediation of contaminated sites.

3.4.4.2 • Transportation

The transportation area accounts for about 27% of the energy used in the United States and about two-thirds of the nation's oil consumption. Imports of petroleum

($45 billion in 1992) and of vehicles and parts ($39 billion in 1992) account for slightly more than 10% of U.S. imports, while motor vehicle and equipment manufacturing is the largest U.S. manufacturing industry. In addition, transportation contributes about one-third of the total U.S. greenhouse gas emissions. Improving the energy efficiency of transportation and lessening the environmental impacts of vehicle manufacturing and operation can play a significant role in reducing pollution and improving the nation's trade balance.

ORNL's transportation research program is the largest and most diversified in the DOE system. Its activities support the needs of DOE, other federal agencies, and industry. For DOE-EE, ORNL conducts R&D on materials, ignition and combustion, alternative fuels, and innovative manufacturing and finishing processes (see Sect. 2.2.3.2). Much of this work is related to the Partnership for a New Generation of Vehicles, which focuses national laboratory capabilities on the needs of U.S. automobile manufacturers. At its Center for Transportation Analysis, ORNL conducts R&D on transportation energy and environmental issues, national transportation planning and policy, military transportation and logistics, and transportation systems engineering, focusing on multimodal national and international transportation systems. Customers include DOD, the U.S. Department of Transportation, the EPA, the Department of Commerce, and the Bureau of the Census.

Through the Tennessee Transportation Coalition, ORNL and its principal governmental, academic, and industrial partners in the region pursue important opportunities in transportation research. The coalition has played a key role in the development of the National Transportation Research Center (NTRC), a partnership of DOE, ORNL, and the University of Tennessee. The NTRC provides a mechanism for promoting and supporting research activities focused on major transportation R&D issues related to energy, environment, and security for the nation and the world. A research and user facility to be constructed at a location between ORNL and the Knoxville campus of the University of Tennessee will be the physical home of the NTRC, which will also operate as a virtual laboratory. Partnerships within the Oak Ridge complex and with other public and private agencies and commercial industry will facilitate transportation R&D. One example is the National Safe Skies Alliance (NSSA), established to assist the Federal Aviation Administration and other agencies in meeting evolving needs in aviation safety and security by supplying affordable, verified solutions to problems identified by the aviation community. The NSSA combines public and private resources to create a systematic framework for addressing these needs, with an emphasis on integrated systems solutions.

ORNL possesses extensive resources in hybrid systems, advanced batteries, and fuel cell technologies. These resources will support the development of clean and efficient fuels in support of the national Climate Change Technology Initiative (see Sect. 3.4.2.4). As DOE's lead laboratory for electric vehicle and fuel cell technologies, ORNL will seek broader programs in these and related areas to support the emphasis on clean and efficient fuels, maintain and extend its strengths, and implement technical advances resulting from past and current programs.

3.4.4.3 • Disposal of Unexploded Ordnance

Unexploded ordnance (UXO)—a category encompassing land mines, ordnance from past military conflicts, and munitions at testing facilities, as well as stockpiled munitions—is a serious global problem. The U.S. State Department estimates that 85 million to 100 million antipersonnel mines, which can remain active for decades, are in place in 70 countries, where

they affect millions of square meters of land, primarily in rural areas. The United Nations estimates that 2 million new antipersonnel mines are laid each year during internal and regional conflicts. Millions of mines and huge quantities of ammunition, stockpiled throughout the world, will need to be safely disposed of during the next decade.

The Congressional Research Service and the International Committee of the Red Cross estimate that every year about 24,000 people around the world are either killed or injured by antipersonnel mines. Aside from the personal toll, medical and rehabilitation costs drain national resources. Land mines can also increase the difficulty of relocating refugees and disrupt economic activity in communities and entire regions.

Domestically, the United States faces a serious and costly challenge in locating and cleaning up areas that have served as training grounds for troops or testing and storage sites for military ordnance and weapon systems. Many of these sites will eventually be transferred to civil or other less restricted uses. Other sites will remain active test and training ranges; these must be cleaned up and maintained to permit continued safe use.

There is a critical need to accelerate the worldwide clearing of UXO. Several U.S. and international governmental agencies, as well as nongovernmental organizations (NGOs), are prominent in demining efforts: DOD, the State Department, the Agency for International Development, the World Bank, the Red Cross, the United Nations, etc. DOD plays an important role domestically, and DOD and the State Department play key roles in providing technical assistance, equipment, and financial resources to international programs.

The DOE national laboratories have developed and tested sensors for detection, as well as technology for removal and remediation of hazardous materials, to support DOE missions in energy resources, environmental quality, and national security (including treaty verification). Work sponsored by DOE, DOD, and other agencies has resulted in a variety of technologies that could be useful in mine detection and clearance. Until recently, however, there has been no coordinated effort to maximize DOE's potential contribution to solving the UXO problem. Such an effort is needed to develop and transfer technology and know-how to support the detection and safe removal of UXO.

ORNL has worked with other DOE laboratories, DOE operations offices, and DOE Headquarters to organize an Interlaboratory UXO Task Force. This Task Force is working to coordinate collective DOE R&D capabilities and to facilitate the exchange of information on the UXO requirements of DOD and other agencies. In December 1996, the Task Force released an initial database of more than 60 DOE technologies that support these requirements. As a result, DOD invited representatives from DOE Headquarters and ORNL (representing the major DOE laboratories) to participate in DOD's UXO Clearance Steering Committee. In addition, the Task Force initiated a memorandum of understanding (MOU) for cooperative DOD/DOE UXO programs. The MOU has been signed by representatives of DOE-NN and DOD's Office of Science and Technology. Follow-up coordination meetings between the two agencies are held each month. These interactions have highlighted the wide range of ongoing DOE-sponsored R&D on technologies that may be useful in developing more cost-effective solutions for detection and safe removal of UXO for DOD's five UXO mission areas.

The scope of the UXO problem spans five major mission areas (see Fig. 3.2): UXO environmental remediation, active range clearance, humanitarian demining, explosive ordnance disposal, and countermine (CM) technology. Technical requirements for each area differ somewhat; however, technology is needed in all areas, and in some cases a technical solution can meet needs in more than one area. For example, R&D is needed to improve

current technologies for detection and removal. There is a particular need for systems that can combine data from different sensors (data fusion) to improve speed and reliability in recognizing surface and buried objects (target recognition).

Technologies developed by DOE laboratories can be used to detect, mark, remove, and dispose of unexploded ordnance (UXO) and land mines. These technologies could contribute significantly to domestic and international demining efforts. Recommended thrust areas are listed in Table 3.7.

DOE plans to establish a budget line item for a cooperative R&D, testing, and evaluation program in UXO detection and safe removal. Program costs will be shared with DOD, the State Department, and other agencies involved in ordnance clearance. Within DOE, work will be coordinated by DOE-NN and closely integrated with other programmatic efforts within DOE, at DOE headquarters and operations offices, and with the program activities of other agencies.

The DOE Interlaboratory UXO Task Force will play a key role in conducting the cooperative ordnance R&D program. Resource projections for ORNL participation in the UXO effort are shown in Table 3.8.

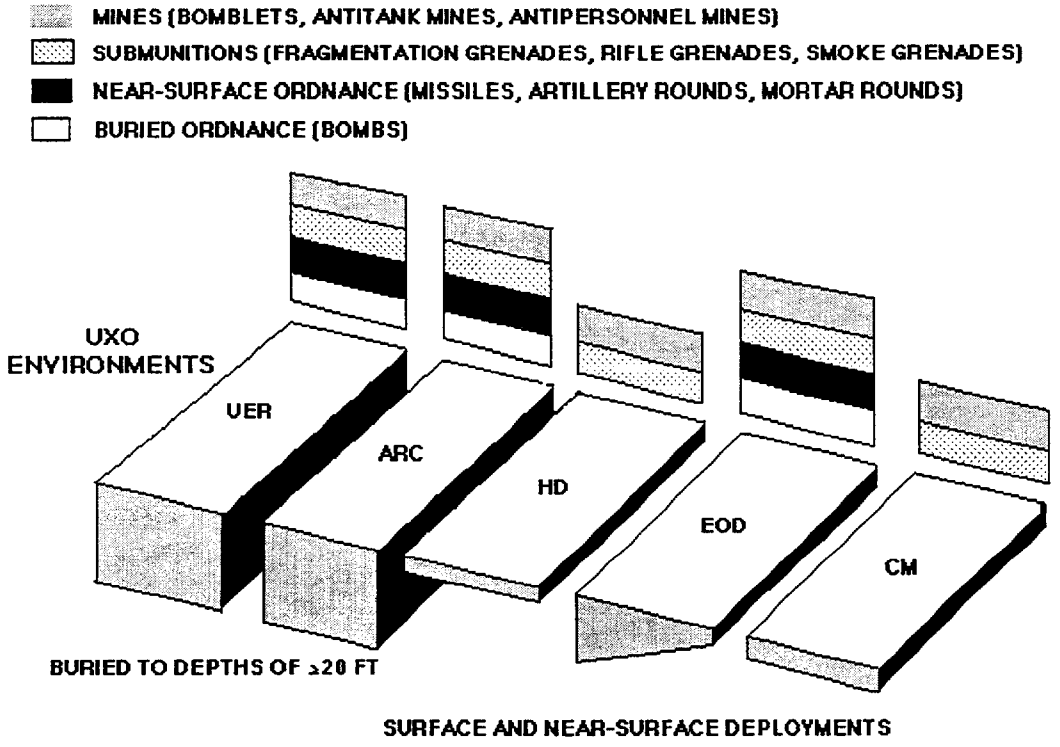


Figure 3.2
UXO mission areas and types of munitions in each environment. UER = UXO environmental remediation; ARC = active range clearance; HD = humanitarian demining; EOD = explosive ordnance disposal; CM = countermine technology.

Table 3.7
Recommended thrust areas for UXO disposal

	Near term (1–3 years)	Middle term (4–6 years)
Sensor development	• Electromagnetic: photon back-scatter, quadrupole resonance • Chemical detection: ion trap mass spectrometer • Radar: micropulse radar, ground-penetrating radar • Data fusion: hyperspectral imaging	• Bioreporters (natural and genetically engineered) • Electromagnetic: resonant antennas • Nuclear: neutron activation • Chemical: microcantilevers
Marking	• Robotics/telerobotics • Ultrasonic ranging and data system • Global positioning systems	• Intelligent microrobotics
Removal	• Remote excavation and operations	
Disposal	• Explosive thermite charges • Physical detonation • Remote handling	• Chemical and biological neutralization • High-power laser detonation

Table 3.8
Funding projections for UXO disposal by fiscal year
($ in millions—BA)

	1999	2000	2001	2002	2003
Operating	2.0	4.0	8.0	10.0	10.0
Capital	0.2	0.2	0.3	0.3	0.3
Total	2.2	4.2	8.3	10.3	10.3

3.4.4.4 • Collaborative Technologies

Collaborative technologies to enable geographically distributed scientific research and efficient management processes are quickly becoming the focus of many initiatives in government, industry, and education. The increasing government interest in and emphasis on collaborative technologies research is demonstrated by

- the DOE 2000 program co-sponsored by the DOE-SC Office of Computational and Technology Research;
- programs in intelligent collaboration, visualization, and information management sponsored by the Information Technology Office of the Defense Advanced Research Projects Agency (DARPA);
- Army Research Laboratory requests for proposals for research in database technology and proposals that focus on innovative uses of Internet web technologies as a primary user interface into a wide variety of enterprise-wide business applications that use Army Standard Systems; and
- the collaborative systems effort sponsored by the U.S. Air Force Common Operating Environments (COE) Branch to provide information solutions to DOD.

ORNL's Collaborative Technologies Research Center (CTRC) performs fundamental research in computing and communications to support the bringing together of adaptive tools, languages, and problem solvers in real-time collaborative environments. It provides

resources for focused, coordinated, and synergistic research that explores the use of advanced information technologies to solve complex systems integration problems in distributed, networked information systems.

CTRC's research agenda defines and establishes real-time collaborative computing as the paradigm of choice for the next century. Real-time collaborative computing will make it possible to combine applications, information sources, instruments and/or facilities, and human interaction, resulting in a real-time multidisciplinary decision-making environment. The capabilities that the CTRC is pursuing will have broad applicability in science, education, business, entertainment, and national defense.

The CTRC strives to organize collaborative software components funded by DOE for individual and joint research projects. By carrying out organizing functions, the CTRC helps DOE to collect, evaluate, filter, organize, and disseminate software and information produced by researchers participating in DOE 2000, the Accelerated Strategic Computing Initiative, Grand Challenge projects, and other activities.

The goals of the CTRC are to

- mobilize and focus the resources of the ORNL Computer Science and Mathematics Division and the Laboratory in the fields of collaborative technologies;
- adopt and develop state-of-the-art collaborative technologies under the auspices of the center;
- initiate a number of projects on collaborative technologies in cooperation with leading organizations;
- become a nationally and internationally recognized research center; and
- spin off the developed technologies to the commercial market.

4 • Major Laboratory Initiatives

To extend the nation's capabilities in key areas of science and technology, the Oak Ridge National Laboratory (ORNL) proposes major initiatives in neutron sciences, functional genomics, and distributed computing. These initiatives are provided for consideration by the Department of Energy (DOE). Inclusion of an initiative in this plan does not imply DOE approval of or intent to implement the initiative.

4.1 • Neutron Sciences

Neutrons play a vital role in many areas of science and technology. They provide an ideal probe of the structure and dynamics of condensed matter; they are useful in the study of magnetic structure and dynamics; and, because they are highly penetrating, they can be used to study bulk materials nondestructively, an application of obvious interest for industry. In addition, the ability of neutrons to transmute matter leads to invaluable applications such as the production of isotopes for use in medical, industrial, and military applications, and neutron activation analysis (NAA) for environmental, commercial, and forensic analyses.

ORNL's strengths in neutron science constitute an integrated capability that spans programs across the entire Laboratory. This capability dates from the 1940s and has included many facilities over the years. Two major in-house facilities at present are the High Flux Isotope Reactor (HFIR) and the Oak Ridge Electron Linear Accelerator (ORELA) pulsed neutron source. The HFIR supports world-class research, production, and testing programs in neutron scattering, NAA, isotope production, and material irradiation testing. Research at ORELA now concentrates on nuclear astrophysics and basic neutron properties (e.g., neutron electric polarizability) research; ORELA is available for other applications, such as target experiments for the proposed Spallation Neutron Source (SNS), and as a positron beam facility. Measurements made on ORELA also support DOE's Nuclear Criticality Predictability Program.

In addition to neutron sources, facilities supporting ORNL's broad neutron science programs include the Radiochemical Engineering Development Center, the Radioisotope Development Laboratory, the Transuranium Research Laboratory, and the Irradiated Fuels Examination Laboratory. The calutrons of the Isotope Enrichment Facility are available to separate stable isotopes and can also make feedstock for radioisotope production. NAA capabilities are essential to a wide range of research (including medical and historical research) and operational projects (including pollutant detection and tracing) for customers inside and outside ORNL.

ORNL is engaged in a major initiative to ensure that the Laboratory continues its stewardship of neutron science in support of DOE's science and technology missions. This initiative incorporates the following activities:

- Design and construction of the SNS, a next-generation spallation neutron source facility, in collaboration with four other DOE national laboratories.
- Upgrades and refurbishment of the HFIR, which would greatly enhance the neutron science capabilities of the world's highest-power research reactor and extend its life well into the next century.
- Establishment of a Joint Institute for Neutron Sciences, in cooperation with the University of Tennessee, to accommodate the 1000 to 2000 users expected each year from universities, U.S. industry, and other laboratories.

4.1.1 • Spallation Neutron Source

The Spallation Neutron Source (SNS) is an accelerator-based, next-generation neutron scattering facility scheduled to be built on the Oak Ridge Reservation. It will produce neutron beams that are 6 to 10 times more intense than any existing pulsed source, enabling researchers to "see" never-before-observed details of physical and biological materials, ranging from high-temperature superconductors to proteins. The SNS is the top-priority project of DOE's Office of Science (DOE-SC), which has committed approximately $39 million through FY 1998 for its design and preparation (see Table 4.1). It will support DOE's strategic goal in science and technology by significantly improving the nation's capability for conducting high-quality, innovative research.

Neutrons will be produced at the SNS by bombarding a mercury target with 1-GeV protons. The protons will be produced by an accelerator system consisting of a hydrogen ion source, a linear accelerator (linac), and an accumulator ring that delivers pulsed proton beams with an average power of 1 MW, at a frequency of 60 pulses per second, to the mercury target. Under these conditions, a typical proton will release 20 to 30 neutrons through a nuclear reaction process called spallation. The neutrons will be slowed to useful energies in water or liquid hydrogen moderators and guided into experimental areas, where they will be used in neutron scattering experiments. When operational, the SNS will serve 1000 to 2000 users each year; thus, its performance requirements and instrumentation needs are being determined in close collaboration with the scientific user community.

The SNS project began in FY 1996, when DOE-SC directed ORNL to initiate research and development (R&D) and conceptual design studies. To carry out these studies, ORNL formed a collaborative arrangement with four other national laboratories: Argonne, Brookhaven, Lawrence Berkeley, and Los Alamos. This SNS Collaboration, which will continue through the project's construction and operation, accesses DOE's best technical expertise and newest technologies, as well as its vast experience with user programs involving scientists and engineers from universities, industry, government laboratories, and institutions in other nations. The SNS Collaboration completed its conceptual design report (CDR) in May 1997, and in June 1997 the CDR underwent review and validation by DOE-SC. The review committee consisted of 65 scientists, engineers, and business leaders from the United States and Europe. The committee strongly endorsed the SNS Collaboration, its reference design, technical scope, cost, schedule, and collaborative management approach.

In FY 1998, DOE-SC provided $23 million to prepare for a construction start in FY 1999. Following a second major readiness review in June 1998, DOE-SC concluded that

the SNS team was ready to initiate Title 1 design and construction activities beginning October 1, pending Congressional approval of funding.

The Energy and Water Development Appropriations Act for 1999, which was signed by the President on October 7, 1998, includes $130 million and a construction line item for the SNS in FY 1999. A DOE-SC Level 1 review will be held in January 1999 to rebaseline the SNS project based on the new Congressional allocations. The present baseline funding profile, which will be rebaselined, is shown in Table 4.1. An architect-engineering/construction management (AE/CM) firm has been selected to assist the SNS in these activities, which began in October 1998.

A draft environmental impact statement that analyzes the proposed ORNL site and alternative sites is being prepared. No site-specific work will be done until the environmental review process is completed.

Table 4.1
Preliminary funding profile for the Spallation Neutron Source by fiscal year
[budget authority (BA) in millions of actual year dollars]

1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Total
8	8	23	157	214	268	263	195	97	100	1,333

4.1.2 • High Flux Isotope Reactor Upgrade

The HFIR is one of the world's most important research reactor facilities. At its current operating power of 85 MW, it has a peak thermal neutron flux of 2.6×10^{15} neutrons per square centimeter per second, highest in the world. This gives the HFIR unique capabilities for producing important radioisotopes and providing facilities for materials irradiation, neutron activation analysis (NAA), and neutron beam scattering studies.

The proposed SNS (see Sect. 4.1.1) will serve many of the needs of the neutron scattering research community and provide significant improvements over existing beam scattering facilities worldwide for many experiments. However, the HFIR will remain the facility of choice for important classes of scattering experiments requiring steady-state beams and for radioisotope production, materials irradiation, and NAA.

To continue these missions, upgrades are needed at the HFIR to modernize some of its instruments and components, to add new capabilities, to increase its power level, and to maintain or improve the availability of neutrons to researchers. The HFIR has been in operation for 30 years, and many of its control instruments and components are increasingly difficult to repair. Spare parts are scarce and sometimes impossible to find, and vendors no longer manufacture some components. In some cases, new technologies have led to more reliable, more accurate components that could reduce error margins and thereby enhance reactor safety and efficiency. Although many major components have been (or will soon be) replaced or refurbished, remaining minor instruments and components are based on technology that is now more than 30 years old. Thus, replacing some of these instruments and components is both desirable and cost-effective.

The complete HFIR upgrade package would

- return the HFIR to 100-MW operation and improve operations;
- increase the size and flux of existing neutron beams;
- add a cold neutron source and an experimental guide hall;
- add five thermal neutron beam guides, a thermal neutron guide hall, and new instrumentation;
- improve user access;
- add a neutron radiography/tomography facility; and
- improve isotope production, materials irradiation, and NAA capabilities.

The DOE-SC Office of Basic Energy Sciences has identified program funds to complete the new cold neutron source, install it in the HFIR, and make the necessary modifications to the HFIR to support the five thermal neutron beam guides. Coupled with the steady upgrading of instrumentation over the last few years, these changes will make the HFIR the most intense source in the world for thermal neutron research and will make its cold neutron source capabilities competitive with the world's best.

The capabilities resulting from the addition of the cold neutron source will support world-class fundamental and applied research programs and could provide the key to new discoveries and applications for plastics, alloys, and biochemical systems. As a complement to the capabilities of the SNS, they will address important needs of the neutron scattering research community. It is expected that the cold source will be installed in FY 2000 during the routine replacement of the HFIR reflector.

The thermal neutron scattering upgrade, to be completed in FY 2000, will include enlarged beam tubes, new monochromator drums, and extension of the HB-2 beam line into the existing HFIR beam hall using neutron guides. The HB-2 extension will provide space for existing neutron scattering instruments displaced by the cold neutron source. Neutron guides work like fiber-optic guides—they are rectangular conduits whose inside surfaces may be coated with one or more layers of material that will reflect any neutrons that strike the surface at a glancing angle, if they are not traveling too fast. Thus, the guides can bring neutrons from close to the reactor, in a series of ricochets, to an instrument more than 30 m (100 ft) away, with little loss. A large thermal neutron guide hall, into which these beam guides could be extended to as many as 15 spectrometers, has been proposed. This hall would provide more space for instruments in a low-background area outside the reactor building. It would also increase the number of users that could be accommodated by increasing the number of beams and instruments. Office and laboratory space would be provided in the new hall for outside users and for ORNL researchers.

The upgrade package also includes the addition of two or three hydraulic access tubes and other changes to improve access for radioisotope production, in support of the ORNL isotopes program, and enhancements to the NAA mission, such as the addition of a prompt gamma facility and delayed-neutron counting capabilities.

With these improvements, the HFIR can continue to operate for another 30 years or more and will provide a unique resource for neutron-based science.

4.1.3 • Joint Institute for Neutron Sciences

The State of Tennessee, through the University of Tennessee, has committed $8 million for the establishment of the Joint Institute for Neutron Sciences (JINS). JINS will be operated jointly by ORNL and the University of Tennessee and will serve as an

intellectual focus for neutron science. In addition, JINS will serve as the gateway for the guest scientists and engineers expected to use the SNS and the upgraded HFIR, which will provide, respectively, the most intense pulsed and steady-state neutron beams available anywhere. The combination of these neutron science capabilities and the presence of JINS will enhance Oak Ridge's position as a leading center for neutron scattering research.

4.2 • Functional Genomics

Large-scale sequencing of the human genome has begun and is expected to produce several million base pairs every day for the next five to ten years. This will provide the biomedical research community with a computerized catalog of the names, locations, and nucleotide sequence of the 80,000 to 100,000 genes on the human chromosomes. Given the rate at which sequence data are being produced, there is the potential for discovering some 75 new human genes every day.

In addition, intense efforts are under way to sequence the genomes of important pathogenic and environmentally and commercially significant microorganisms. Increasing focus is also being placed on sequencing plant genomes, with obvious implications for agricultural crops. Several of these smaller genomes have been completely sequenced.

Significant advances in the ability to determine the function of genes, within and across genomes, are required to unlock all the information hidden in the output from sequencing and gene searches. Biologists have been studying gene function for many years, but most of their research has been slow, costly, and directed at single genes. Access to the powerful reagents from the genome program is changing this situation. In the new era of biomedical research that is now beginning, it will be possible to perform experiments in functional genomics—that is, to determine the function of genes and systems of genes on a genome-wide scale.

Gene function is determined (1) by analyzing the effects of DNA mutations in genes on normal development and health in the whole organism; (2) by analyzing a variety of signals encoded in the DNA sequence; and (3) by studying the proteins produced by a gene or system of related genes. Researchers are able to study functional genomics in humans by using genome information from other model organisms that provide rich scenarios for experimental research. The mouse, with its genetic and physiological similarities to the human and its extensive comparative genetic linkage map, is one of the leading model organisms for determining human gene function. A wide variety of genetic and molecular manipulations are possible in the mouse, making it a powerful research organism for studies of functional genomics.

In addition, the availability of completed DNA sequences for plants and microbes opens opportunities to work on gene networks and gene interactions in systems where all the genes are known. Work on other model organisms also opens related research areas that are important to DOE, such as the identification of organisms in the environment and the genetic manipulation of organisms to help mitigate environmental problems.

4.2.1 • Overview of Present ORNL Program

Functional genomics at ORNL is a comprehensive effort that leverages extensive expertise and facilities in mammalian genetics, plant genetics, bioinformatics and computational biology, biochemistry, and environmental microbiology and the Laboratory's resources for cutting-edge technology development.

The ORNL Mouse Genetics Research Facility (MGRF), a DOE national user facility, is an unparalleled resource for functional genomics. The MGRF represents one of the largest facilities in the world for carrying out experimental research in functional genomics using the mouse as a model organism. Mouse geneticists can "target" a specific gene to eliminate or alter its function in the whole animal or only in a specific cell population, or they can add normal genes back to a mutant mouse to correct an abnormality. They can engineer rearrangements in large regions of the genome and then create gene-by-gene mutations in these regions using the chemical mutagen ethylnitrosourea (ENU) to make single-base changes in DNA. ENU was identified as a "supermutagen" at ORNL, and its effective use in mutagenesis experiments in the mouse was pioneered here. It is useful for making multiple different mutant forms of a single gene, thereby providing more exact human disease models that mimic the subtle genetic variations characteristic of human populations. These strategies for creating mutations in mice can easily be expanded to a genome-wide scale, generating genetic reagents essential for the entire research community.

ORNL has been developing resources in bioinformatics for the genome research community since the early 1990s, starting with the Gene Recognition and Analysis Internet Link (GRAIL) DNA pattern analysis system. GRAIL is a suite of tools that provide analysis and putative annotation of DNA sequences both interactively and through automated computation. Its capabilities are available through an electronic mail (e-mail) server at ORNL, which processes DNA sequences contained in e-mail messages, and an interactive client-server system called Xgrail, which supports a wide range of analysis tools, including gene modeling. The ORNL genome informatics resource is being used by thousands of researchers worldwide. ORNL informaticists and computational biologists lead the Genome Annotation Consortium, a collaborative effort that involves several bioinformatics groups at other national laboratories and universities and is focused on providing the analysis tools and information access and processing environment appropriate for effectively managing the enormous amount of data produced by large-scale genome sequencing.

Another critical component of the Functional Genomics Initiative at ORNL is the ability to quickly characterize the structure and function of the proteins that genes encode. This involves a comprehensive effort that integrates protein engineering and enzymology, mass spectrometry, neutron-based structural biology, and computational approaches to the prediction of protein structure and of protein function based on structure.

The large number of genes to be analyzed and the extraordinary complexity of analyzing the function of systems of genes and their interrelationships make it necessary to develop high-throughput technologies with the potential to lead to truly genome-wide determination of gene functionality. ORNL is addressing these needs through a number of technology-oriented efforts that include genosensor-type chip arrays, fast DNA analyses employing the "Laboratory-on-a-Chip" concept, and other microinstrumentation developments for genome analyses.

To support this comprehensive effort, ORNL senior managers made a commitment to invest a portion of Laboratory Directed R&D (LDRD) funds in this area for a three-year

startup period (FY 1997–FY 1999). LDRD projects supported by this commitment are carried out by teams representing many ORNL divisions, including Life Sciences, Chemistry and Analytical Sciences, Instrumentation and Controls, and Robotics and Process Systems.

These projects are leading to advances in several areas. New programs have been established in ENU mutagenesis and testing of potential mutants for genetic changes in behavioral and biochemical parameters; behavioral aberrations in 4 existing mutant strains have been documented for publication, and 176 new litters have been screened for induced mutations in a large segment of mouse chromosome 4. ENU was also used to generate multiple alleles at two mouse loci involved in immune function. New recessive alleles of each locus were obtained, and eight new dominant mutations with relevant human disease phenotypes have proven to be heritable. Researchers are developing new technologies for automating screening techniques to relieve bottlenecks now caused by reliance on manual testing protocols. A database for deletion complex information was created to make information about chromosomal deletions in the mouse available to the research community, with a Java interface to view deletion complexes and function data in mice and to make correlations and comparisons to human data. An online resource on mouse mutant strains at ORNL was made available. The informatics effort is designing and developing a comprehensive and assembled sequence-based framework for gene function studies. This includes an automated system to capture sequences as they are generated worldwide, to analyze these sequences for new genes, and to make the information accessible to the genome community via the "Genome Channel Browser." This work also addresses the development of a system that uses World Wide Web/Internet agents to dynamically locate and link to remote information about the function of known genes.

The LDRD investment is now generating new funding. The DOE-SC Office of Biological and Environmental Research (OBER), through its Joint Genome Institute, is providing startup funds for projects in informatics and embryonic stem cell–based mutagenesis. Genosensor development has been supported by a commercial partner through a cooperative R&D agreement.

As part of a comprehensive marketing approach aimed at commercial research partners, the ORNL functional genomics team organized a conference, "Partnering for Functional Genomics Research," April 16 and 17, 1998, in Oak Ridge. The event featured detailed briefings, a poster session, and laboratory tours presenting the functional genomics initiative. Representatives from 14 pharmaceutical and biotechnology companies participated in the meeting. All participating companies expressed interest in further interactions. Follow-on activities are under way to establish collaborative efforts and to pursue the development of an R&D consortium involving several industry partners.

4.2.2 • Center for Biological Sciences

OBER is planning for a significant investment in a new Center for Biological Sciences (CBS) at ORNL during the FY 2000–FY 2004 period. The CBS is planned as a modular complex of buildings, equipment, and infrastructure that will house current and future research programs in the areas of functional genomics, structural biology, proteomics, and systems biology. It will provide the environment for the ORNL biological research program to make significant contributions to the next decade of biology and beyond, with a special focus on complex biological systems research. Development of the CBS will enhance the advantages gained from the program's recent restructuring to embrace not only the

biological sciences but also allied disciplines in information science and computing, analytical methodologies, and chemistry. Table 4.2 provides funding projections for the CBS.

The first phase in the development of the CBS is the construction of a Laboratory for Comparative and Functional Genomics (LCFG), at an estimated cost of $12 million, to house the MGRF. The LCFG will replace an aging building at the Oak Ridge Y-12 Plant that is no longer adequate to house one of ORNL's premier research facilities. In addition to housing the mouse colony, the LCFG will include laboratories with special phenotype screening and cryopreservation capabilities.

The CBS will also encompass a Center for Structural Molecular Biology (CSMB), a user facility that will integrate ORNL's unique capabilities in neutron science, as represented by the HFIR and the SNS (see Sect. 4.1), with strong programs in mass spectrometry and computational biology. The SNS beam line identified in Table 4.2 is the principal new resource needed to support the CSMB.

Laboratory resources in bioinformatics and computational biology, described in Sect. 4.2.1, will add to the scientific stature of the CBS. Efforts in these areas link the functional and structural biology components and also support the development of new efforts in systems biology envisioned as part of the CBS. The CBS will provide space and "connectivity" (computing and information technology infrastructure) for both the bioinformatics and computational biology researchers and the experimental biologists. The leverage gained through this combination of expertise and infrastructure will also provide the tools for use of the CBS facilities as a virtual laboratory by research partners at other institutions.

Research programs at the CBS will encompass ORNL's important efforts in protein biochemistry, which were recently recognized with the election of a senior staff member to the National Academy of Sciences. The CBS will provide the physical environment for integrating these efforts into ORNL's biological research program and bringing them to bear them on the broader charge of proteomics (the study of the proteome, that is, all of the proteins coded by the genome of an organism).

Future biological research at ORNL will be aggressively directed to take advantage of advances not only in computational biology but also in instrumentation and measurement sciences and technology. Facilities at the CBS will co-locate bioinstrumentation and bioengineering R&D efforts with the new biological research programs. These programs will build strong alliances with other biological and medical research centers, building on the resources of the Joint Institute for Biological Sciences (see Sect. 4.2.3).

Table 4.2
Funding projections for ORNL Center for Biological Sciences by fiscal year
(in millions of dollars)

	2001	2002	2003	2004
Laboratory for Comparative and Functional Genomics	8	4	0	0
Structural biology beam line for the Spallation Neutron Source	0	0	3	3
Computational biology and bioinformatics	2	3	0	0
Proteomics	3	5	2	0
Instrumentation	2	1	1	1
Total	15	13	6	4

4.2.3 • Joint Institute for Biological Sciences

ORNL and the University of Tennessee (UT) have established the Joint Institute for Biological Sciences to promote and develop support for collaborative R&D in the biological sciences. The initial phase will focus on strengthening the partnership between ORNL and UT and developing or expanding collaborative efforts in functional genomics, structural biology, and computational biology and bioinformatics. This phase will include the integration of the ORNL-UT Graduate Program for Genome Science and Technology into the Joint Institute. The second phase in the evolution of the Joint Institute will explore new areas such as forensic sciences, biomimetics and biomaterials, and biomedical technologies.

Under the direction of a scientific advisory committee, the Joint Institute for Biological Sciences will provide new opportunities for applying the complementary capabilities of ORNL and UT to emerging problems in the biological sciences. It will also support the integration of research and education, exposing students to the multidisciplinary approaches needed to understand complex biological systems. A strong interface with the UT Medical Center is envisioned to support the effective transfer of R&D results to clinical applications, and distance learning capabilities at ORNL and UT will enhance opportunities for national and international participation in research conducted under the auspices of the Joint Institute.

An acting director has been named, and work is under way to create a planning committee that will develop a strategic plan outlining specific goals for R&D, staffing, facilities and equipment, and funding. Other tasks to be undertaken during the planning period include establishing a scientific advisory committee and securing start-up funding.

4.3 • Teraflops Computing and Simulation Science

4.3.1 • New Directions in Computation and Simulation

The use of computational tools is vital to essentially all fields of science and engineering. These tools enable the realistic simulation of physical situations, providing new insights into a host of scientific problems. Indeed, simulation has now joined the traditional approaches of experiment and theory as a fundamental avenue to understanding.

Improvements in computer performance during the past decade have been dramatic—a trend that promises to continue. Massively parallel computers that exploit advances in microprocessor technology offer the enormous computational power needed in solving Grand Challenge problems. Distributed computing, which applies networked computers to the solution of a single large problem, is a major trend in scientific problem solving. Advances in electronic collaboration and advanced computational tools are supporting efficient use of research facilities and the creation of "virtual laboratories."

ORNL has played a leading role in these advances. The Laboratory has been at the forefront in acquiring and evaluating massively parallel computers and bringing them to production status. The worldwide popularity of distributed computing can be traced in large part to ORNL's development of the PVM (Parallel Virtual Machine) software for efficiently linking computers into networks. ORNL has also contributed to advances in parallel code development, in data storage systems and software, and in visualization and networking. The

linking of the Intel Paragon computers at ORNL and Sandia National Laboratories to solve formidable computational problems represents success in addressing a range of challenges in wide-area metacomputing. ORNL's work on the Electronic Notebook, the Collaborative Management Environment, and the Materials Microcharacterization Collaboratory has contributed to more effective collaborations and more efficient use of DOE resources.

DOE is now exploring an initiative that points to new opportunities in—and expectations for—computational science. The Scientific Simulation Initiative (SSI) is a proposed investment to take the nation into a new era of information and communications technology. It will rapidly deploy computing and communications capability that is at least 10 times faster than today's fastest systems for government, academic, and industrial use. This capability will revolutionize current approaches to solving complex problems in energy, environment, fundamental research, and technology development, and it will stimulate the national system of innovation.

Attaining the proposed capability will demand significant advances in computational resources. Fully exploiting the power of massively parallel machines requires the creation of new programming paradigms, languages, scheduling and partitioning techniques, and algorithms, and all of these elements must be integrated into systems that are accessible and useful to a diverse user community.

4.3.2 • ORNL Resources and Opportunities

As DOE's most programmatically diverse national laboratory, ORNL conducts a broad range of theoretical and experimental programs (see Sect. 2.3.3). ORNL is also home to a comprehensive computational science effort that leverages extensive expertise in the application of computing to physical problems and excellent facilities for massively parallel high-performance computing to answer scientific questions and to advance the development of computational resources.

- The ORNL Center for Computational Sciences (CCS) is the focal point for the development and application of innovative computational systems and tools. Resources include three Intel Paragon systems, a 150-terabyte data storage and access system, extensive efforts in parallel code development and in strategies for wide-area metacomputing, and a broad range of visualization and networking systems and expertise.
- The Computational Physics and Engineering Division (CPED) offers capabilities in computational physics, computational engineering, integrated computing applications, and nuclear engineering computations and analysis. CPED has a 30-year history of applying computers to physical science problems relating to energy, the environment, and health and safety research.
- The Computational Science and Mathematics Division (CSMD) is a world leader in basic research in heterogeneous distributed computing, applied mathematics, and collaborative technologies. CSMD also carries out basic research in quantum computing, cooperating autonomous systems, and nonlinear science. Ongoing applied research projects include computational materials science, global climate simulations, combustion modeling, transportation, genomics, and computational neurosciences.
- The Computing, Information, and Networking Division conducts R&D on high-speed interconnect technology and Next-Generation Internet capabilities for handling distributed computation, control, and collaborative applications for government and industry.

- The Computational Center for Industrial Innovation, a national user facility, supports the application of ORNL's high-performance computing resources to industry needs.

Additional expertise is distributed throughout ORNL: for example, the Chemical and Analytical Sciences Division is exploring computational chemistry and nanotechnology; the Fusion Energy Division uses high-performance computing to address transport phenomena, plasma behavior, heating and current drive, and plasma edge effects in fusion experiments; the Life Sciences Division carries out pacesetting efforts in computational biology and development of computational tools for analyzing the structure and function of genomes, genes, and proteins; the Metals and Ceramics Division is performing large-scale simulations of materials properties, using a hierarchy of increasingly accurate and computationally intensive techniques; and the Physics Division has expanding efforts in computational nuclear structure and computational astrophysics.

These resources are being applied to the development of applications and forefront computing tools that support DOE missions, as outlined in Sects. 4.3.2.1 and 4.3.2.2.

4.3.2.1 • Applications

Climate Prediction

ORNL is a major contributor to the process research and modeling efforts that are advancing the understanding of global climate systems. These efforts include the collection and analysis of data needed to assess the potential for and consequences of global warming; ORNL houses three major repositories of data related to global climate change. Its computing and communications resources are used to ensure efficient storage and rapid retrieval of these extensive data sets and to support data mining and pattern analysis. Simulation will be an important tool in reducing uncertainties in climate predictions and determining the social and environmental consequences of changes in energy use, land cover, and population.

Working with the Argonne National Laboratory and the National Center for Atmospheric Research (NCAR), ORNL has advanced the use of massively parallel computers for climate modeling through the development of numerical methods and parallel algorithms and the implementation of the NCAR Community Climate Model, CCM2, on the Intel Paragon, the Thinking Machines CM-5, and the IBM SP-2. Work to develop new climate models that can take advantage of new levels of supercomputing power continues through DOE's Climate Change Prediction Program.

Future models will close the gap in spatial scales between large-scale circulations in the ocean and the atmosphere and regional climate concerns. Climate modeling an order of magnitude more detailed than existing models is needed to study critical small-length-scale factors. The output of these detailed simulations will make it possible to assess the impacts of climate change on regions such as the eastern or southeastern United States.

With support from the Laboratory Directed R&D (LDRD) program, researchers in the CSMD and the Environmental Sciences Division are working together to establish a prototype regional climate center at ORNL. Plans include coupling general circulation, terrestrial, and regional models and creating an interdivisional computational grid environment.

Combustion

Internal combustion engines have been identified as the source of one-third of pollution and ozone-depleting greenhouse gases. Emerging demands for emission reduction will

require the development of dramatically cleaner and more efficient combustion technologies. Detailed computational models can improve the understanding of combustion, leading to innovative designs that achieve lean fuel limits, low emissions, and high efficiency.

ORNL is developing advanced predictive capabilities for combustion processes to support the design of next-generation vehicles and environmentally responsive technologies. Efforts include the implementation of KIVA-3 (a powerful computational fluid dynamics code from the Los Alamos National Laboratory that is widely used in the design and analysis of internal combustion engines) in a parallel processing environment, thus advancing the solution of large-scale combustion problems on scalable systems.

As a member of the Supercomputer Automotive Applications Partnership, an element of the U.S. Council for Automotive Research, ORNL contributed to the development of a "library" of computer models for engine combustion and vehicle airflow challenges common to all automotive designs. ORNL currently has cooperative R&D agreements with the automotive industry to study combustion as it relates to advanced automotive engine design and with the paper industry for improvements in boiler technology.

Combustion modeling must also address the effects of engine and turbine materials on efficiency and pollutant emission. As a world leader in theoretical and experimental materials science, particularly in the fabrication and analysis of new alloys, ORNL will use advanced materials modeling to design more fuel-efficient automotive engines and turbine blades that can be operated at higher temperatures, with greater efficiency. The CSMD and the Engineering Technology Division are working on an LDRD project to model the catalysis and surface chemistry of catalytic converters in an effort to speed design cycles for these components and improve their ability to remove pollutants from automobile exhaust.

Materials

Scientists at ORNL are using massively parallel processors and newly developed computational methods to simulate the properties and behavior of materials. Insights gained from these simulations, which cost less and take less time than laboratory experiments, are accelerating the development of new, technologically advanced materials that can improve the efficiency and economy of energy production and use, contribute to new technologies, and lead to new products. Work in progress includes the following projects:

- Accurate simulation of the properties of materials whose behavior depends on the electronic structure of systems comprising hundreds to thousands of atoms; until recently, such investigations were considered untenable because of the large number of particles necessary for accurate simulations.
- First-principles calculations of variations of electrical resistivity in layered magnetic alloys, which offer the promise of higher density magnetic data storage systems.
- Simulations of the collisions and transport of energetic ions in crystals; the combination of these simulations with experimental tools at ORNL, such as the *Z*-contrast scanning transmission electron microscope, affords a unique opportunity to study the complex nature of surfaces and interfaces.
- Analysis of material performance in automotive applications, in an integrated effort that comprises developing detailed vehicle models, modeling lightweight materials (a high priority for automotive applications because they can improve fuel economy), and combining these models to analyze material performance during collisions, providing information that would otherwise have to be obtained from expensive crash testing.

Genomics

ORNL has a strong and rapidly growing computational biology and bioinformatics effort, situated in the Life Sciences Division, that is integrated with its programs in functional genomics and biotechnology. This effort is a key element of the major initiative in functional genomics described in Sect. 4.2. The focus is on extending the range of understanding of biological phenomena from molecules to systems, to phenotype and organism function. This understanding is critical to DOE's science and environmental missions.

ORNL has developed DNA sequence analysis tools such as GRAIL (Genome Recognition and Analysis Internet Link), other genome informatics resources, and protein classification and structure prediction tools that are widely used by the international biology R&D community. New tools and approaches are being created to address a variety of challenges. Computational biology, particularly those applications focusing on genome analyses, will require routine and recurrent use of a number of codes, many with teraflops requirements. These codes will be essential for processing and analyzing the approximately 100 megabases of human sequence that should be generated *per day* by mid-1999. High-performance codes—for sequence assembly of hundreds of thousands of "shotgun" sequencing fragments generated per day, for gene recognition and modeling, for assigning the many new genes and proteins to functional families and computing structural folds, and for facilitating large-scale genome sequence comparisons—will be integrated in a coordinated community effort. Developing efforts in structural genomics and computational biotechnology will create a demand for additional computational tools to address detailed molecular structures and even more complex biological systems.

Fusion Energy Sciences

ORNL conducts R&D and design studies in magnetic fusion energy, plasma science, and plasma-based technologies. Researchers in the Fusion Energy Division, in collaboration with CPED and CSMD, have pioneered the application of massively parallel computers and associated programming techniques to fusion calculations and are participating in the Numerical Tokamak Turbulence Project (NTTP), a DOE Grand Challenge. As part of the NTTP's efforts to improve predictions of plasma performance, ORNL researchers have performed large-scale calculations of plasma turbulence and anomalous transport on the Intel Paragon computers at ORNL's CCS and the CRAY T3E systems at the National Energy Research Scientific Computing Center.

ORNL is also pursuing improved models of the edge plasma region. This includes the coupling of edge-modeling packages to atomic physics modules such as those developed as part of ORNL's Fusion Program by the Physics Division in collaboration with Auburn University. Radio-frequency (rf) plasma heating models developed at ORNL will also be extended, with the aim of providing a much higher resolution three-dimensional, full-wave description of rf heating systems, including antenna coupling, wave propagation, and plasma-wave interaction.

4.3.2.2 • Resource Development

As the development of more powerful supercomputers continues, advances in processing power must be complemented by advances in computing, communications, and information tools and technologies. For example, a typical 5-teraflops system requires

2 terabytes of computer memory, 5 petabytes (5×10^{15} bytes) of data storage capacity, and input-output (I/O) capacity exceeding 200 gigabits per second. In addition, operating systems, I/O software, communications software and protocols, visualization systems, data management systems, and network interfaces must all work together with application codes and hardware. Seamless access, secure networks, readily accessible data storage systems, and software and applications must be provided to support user needs.

Hardware and Networks

ORNL has demonstrated an outstanding ability to bring new and immature parallel computers to production performance and innovative use. Using the resources of the CCS, the Laboratory has been successful in

- identifying and eliminating problems in the machines and in interfaces between machines and the "external" world;
- connecting its two largest Paragon computers over high-speed ATM OC-12 networks, thus creating a distributed machine with peak performance close to 200 gigaflops, and
- working with Sandia to link the Paragon computers at the two sites over ATM networks and using the resulting distributed computing power to solve large, complex problems.

Efforts are focused on ensuring compatibility among codes, operating systems, ATM networks, and communications software. Significant questions concerning network connections and network availability are being addressed, and the computational power of the linked computers is producing results that support DOE missions in science and national security. The CCS has extended its distributed computing capability by implementing software developed as part of the Globus project and placing some of its machines on GUSTO, the extensive Globus Ubiquitous Supercomputing Testbed.

ORNL is moving ahead to the task of bringing new teraflops-level systems to effective performance with its selection by DOE to conduct a comprehensive evaluation of the SRC-6, an innovative shared-memory machine being developed by SRC Computers, Inc.

Computer Science and Enabling Technology

ORNL has led the development of several enabling technologies for computer science that have become world-wide *de facto* standards. The PVM software package is used for distributed computing at thousands of sites. The LaPACK and ScaLAPACK packages for high-performance linear algebra are heavily used in commercial and research software. The QMRPACK package and several sparse matrix solvers developed at ORNL are used in a variety of scientific and engineering applications, ranging from first-principles electronic structure codes for Grand Challenge problems in materials science to codes used in the automotive and aerospace industries.

ORNL initiated the development of MPI, the standard Message-Passing Interface, which simplifies the porting of applications between different parallel machines. Other enabling technologies developed at ORNL include CUMULVS, which supports collaborative remote visualization and steering of distributed applications and fault tolerance for long-running simulations; the Electronic Notebook, in use by hundreds of groups around the world; and HARNESS, an adaptable, heterogeneous computing environment being developed to replace PVM. ORNL is also participating in the specification of a Common Component Architecture (CCA) for high-performance computing.

The High Performance Storage System (HPSS) provides a scalable parallel storage system for highly parallel computers, traditional supercomputers, and workstation clusters. Developed by ORNL and the Lawrence Berkeley, Lawrence Livermore, Los Alamos, and Sandia national laboratories in collaboration with IBM, HPSS is designed to manage the petabytes of data produced and used by supercomputers. For example, HPSS can manage parallel data transfers from multiple network-connected disk arrays at rates greater than 1 gigabyte per second, supporting access to high-definition digitized video in real time.

4.3.3 • ORNL Plans

The DOE-SC theme "Extraordinary Tools for Extraordinary Science" recognizes the importance of mathematical and computational tools in predicting the behavior of complex systems and conducting multidisciplinary research. ORNL expects to build on its present role in developing and applying these tools, as outlined in its strategic plan (see Sect. 3).

ORNL also proposes to expand its ability to support DOE's missions by accelerating the integration of simulation, modeling, and computation into its R&D programs. The Laboratory proposes to accomplish this by

- continuing its established emphasis on high-end and distributed computing and participation in national initiatives;
- increasing the Laboratory-wide level of expertise in modeling, simulation, and numerical methods; and
- enhancing the accessibility of its high-performance computational power, within ORNL and throughout the DOE research community, by extending the network infrastructure and establishing at least one multiple-teraflops computational "simulation center."

A computer science research program will address the effective use of distributed computers and massively parallel computer systems composed of symmetric multiprocessing (SMP) clusters linked with high-speed network fabrics. Research into numerical methods and programming environments will be aimed at resolving the software issues associated with using these systems in scientific applications. Collaborative technologies will be deployed to enhance and enable interdivisional projects that use high-end computational resources.

This effort will be of direct benefit to a variety of DOE programs. In particular, these actions will support ongoing programs in environmental sciences, neutron science, materials research, combustion research, and bioinformatics. The following are key steps to be taken during the planning period:

1. Plan and prepare for a world-class machine at ORNL to replace the Intel Paragon computers (estimated time to completion: 12 months).
2. Develop a prototype regional climate center to support climate research studies in the southeastern United States (estimated time to completion: 12 months).
3. Develop one or more simulation centers with significant computational resources for collaborative applications (estimated time to completion: 24 months).
4. Foster a significant expansion of ORNL expertise in simulation and modeling, through mechanisms such as encouraging cross-divisional collaborations that make use of simulation centers (estimated time to completion: 24 months).
5. Plan and install advanced networking facilities to increase the internal connectivity at ORNL and to provide a higher level of connectivity with other DOE laboratories and collaborating institutions (estimated time to completion: 36 months).

Preparation for a world-class machine will include the evaluation of the SRC-6. DOE-SC is funding the purchase of two SRC-6 units, to be combined in a 25-gigaflops system. ORNL will assess the performance of this system on Grand Challenge–level codes in such areas as materials science, computational fluid dynamics, and global climate change modeling. The evaluation will also include detailed studies of node interconnect strategies and systems and novel architectural features of the SRC machines. The results of this evaluation will provide a basis for developing specifications for a successor machine (possibly a multiple-teraflops SRC-7). ORNL will work with the national energy research community to develop these specifications.

ORNL will draw on its experience in successfully implementing large multiprocessor machines and collaborating with other DOE laboratories and institutions with complementary resources and expertise. Activities will also take advantage of ORNL's ability to assemble interdisciplinary teams of computer scientists, mathematicians, and computational scientists to develop the new algorithms, tools, and software needed to take advantage of increases in computing power.

Interdisciplinary work will also characterize the development of a prototype regional climate center. Experience gained in this project will be incorporated into the development of simulation centers. The extension of simulation and modeling capabilities to new areas will be fostered through the encouragement of projects involving multidivision teams (e.g., such projects may receive a higher priority for access to simulation centers).

New tools to support data-intensive computing will be created to manage the large data sets being acquired, for example, to support research in functional genomics and global climate change. ORNL will also continue its work to develop effective tools for visualization and simulation, methods for addressing security issues, and collaborative environments, in collaboration with other DOE laboratories.

Developments in data storage and network peripherals will be aimed at securing a balanced computational environment consistent with a multiple-teraflops system. The resulting increase in connectivity will strengthen collaborations within ORNL and across the DOE system of laboratories. ORNL will continue as a partner in the multilaboratory HPSS collaboration, which is pursuing further improvements in the flexibility, performance, features, and usability of this software. Expertise gained through the ORNL-Sandia partnership will be applied to the development of networks operating in the range of 200 gigabits per second.

Throughout the planning period, the focus of the initiative will be on the development and integration of skills and facilities for computing, modeling, and simulation and the application of these integrated resources to DOE's needs in science and technology. As the SSI evolves, ORNL will work with DOE to explore opportunities for applying the Laboratory's resources to emerging challenges.

5 • Operations and Infrastructure

Operations functions [i.e., functions involving management of the Oak Ridge National Laboratory (ORNL) and support for its core programmatic and research functions] are carried out principally by the Laboratory's Central Management Offices, the Business Management Organization, and the Operations, Environment, Safety, and Health (OES&H) Directorate. ORNL is managed for the U.S. Department of Energy (DOE) by Lockheed Martin Energy Research Corporation (LMER). The management contract between DOE and LMER describes the work and services to be provided by LMER in managing the missions of ORNL "in a manner consistent with the DOE Strategic Plan and the principles of performance-based contracting." Management of ORNL is also governed by the following set of partnering principles, to which the Laboratory and DOE's Oak Ridge Operations Office (DOE-ORO) agreed in January 1996:

- DOE oversight will move from "prescription and permission" management to performance evaluation.
- DOE will not duplicate oversight responsibility which resides in other agencies.
- The intent of oversight will be to assess contractor management systems, commensurate with the risk to DOE.
- The DOE/Laboratory complex will institute outcome-based management assessment and apply best management practices and commonly accepted industry standards.
- Laboratory contractors have full responsibility and accountability for all of their administrative, programmatic, and regulatory functions.
- DOE's role is scientific program definition, stewardship, planning and funding of Laboratory programs and infrastructure, and performance review.
- Consolidate management activities by eliminating redundancy and integrating functions to achieve cost effectiveness.

5.1 • Environment, Safety, and Health

5.1.1 • Integrated Safety Management

ORNL's commitment to integrated safety management (ISM) and to the accomplishment of mission assignments in a safe and effective manner is documented in an ORNL directive, *ORNL Integrated Safety Management Policy Statement,* ORNL-LM-001, January 1, 1998. ORNL is implementing an ISM system (ISMS) to ensure that safety considerations are integrated into the planning and execution of research and support activities. The ORNL ISMS program is described in detail in *ORNL Integrated Safety Management System (ISMS) Program Description,* ORNL-LM-003, July 10, 1998.

As outlined in the program description, each line organization is to have at least one organization-specific ISMS plan to customize the ISMS principles and core functions to its operations. For complex or special-hazard situations, organizations may choose to have additional ISMS plans tailored to specific programs or facilities. Both the program description and organization-specific ISMS plans will be updated as necessary, based on ongoing self-assessment activities that identify gaps to be filled and/or on changes in work scope.

Phase I verification of ORNL's ISMS program is scheduled for March 1999. ORNL expects to validate and fully implement its ISMS program by September 1999.

5.1.2 • Goals and Objectives

The management contract between DOE and LMER establishes fundamental ES&H expectations. The *ORNL Environment, Safety, and Health (ES&H) Policy,* ORNL-LM-004, September 11, 1998, states ORNL's objective of assuring the health and safety of its people and the public and protection of the environment. The policy states, "The prime operational imperatives of ORNL are the health and safety of all employees, guest scientists and engineers, visitors, and the general public and the protection of the environment, including the implementation of a pollution prevention program. ORNL is committed to adhering to applicable federal, state, and local ES&H laws, regulations, and requirements, as defined by the Company's Work Smart Standards."

The ORNL ES&H Policy also documents ORNL's commitment to the following practices:

- Maintaining a goal of preventing serious accidents that result in injuries or environmental contamination.
- Evaluating ES&H performance as part of the employee performance review process.
- Placing strong emphasis on work planning and worker involvement.
- Maintaining a work environment where employees can express ES&H concerns without fear of reprisal.
- Communicating to employees their ES&H responsibilities and Company ES&H goals, and encouraging each employee to assume ownership and responsibility for ES&H performance, including the authority to stop unsafe work.
- Responding to employee, community, customer, and regulatory agency concerns regarding potential ES&H impacts of our operations.
- Participating in public policy processes to promote development of ES&H laws and regulations that are protective of human health and the environment and consistent with sound science and risk management.
- Working with regulatory agencies and customers on proactive initiatives to improve ES&H performance while being more cost effective.
- Conducting periodic assessments of ES&H performance and sharing and utilizing ES&H Lessons Learned and Best Practices in support of continuous improvement.

5.1.3 • Current Conditions

Federal and state regulations, permits, applicable DOE requirements, and a Federal Facilities Agreement (FFA) among DOE, the State of Tennessee, and the Environmental Protection Agency provide a framework for actions to protect human health and the environment, achieve compliance with environmental regulations, and meet public expectations.

Established in 1943, ORNL has one of the oldest physical plants in the DOE laboratory system, with a substantial legacy of ES&H problems that need correction. Several hundred sites at ORNL are contaminated with radionuclides and hazardous chemicals. Contamination of surface water, groundwater, and biota has also been detected and reported. Remediation and waste management activities relating to these issues have been under way for several years. Responsibility for these activities was recently transferred to Bechtel Jacobs Company LLC as part of the management and integration (M&I) contract for DOE's environmental management (EM) programs in Oak Ridge.

ORNL is engaged in basic and applied research and development (R&D) in all of DOE's major businesses. The Laboratory operates several accelerators and a variety of facilities for biological, energy, materials science, and neutron science R&D. Radiation protection for workers and the public is required for accelerators, X-ray units, sealed radiation sources, and radioisotope production, handling, and use. Nonradiological hazards include electrical systems, hoisting and rigging operations, chemicals, biohazards, moving machinery, moving vehicles, construction activities, and natural phenomena such as severe weather.

ORNL also operates one reactor, the High Flux Isotope Reactor. Several other reactors have been permanently shut down and are awaiting decontamination and decommissioning. Because of changing missions, several isotope production facilities have been shut down, and removal of radioactive materials from these facilities is in progress. Current operating missions include the processing of such radioisotopes as ^{252}Cf and ^{192}Ir and the storage of ^{233}U. In addition, more than 35 facilities at ORNL are used for the temporary processing and storage of radioactive, chemical, and mixed hazardous wastes in gaseous, liquid, and solid forms. These facilities include burial grounds, storage buildings, surface impoundments (ponds or lagoons), surplus facilities, and underground storage tanks.

The diversity of ORNL's R&D and support activities creates both challenges and opportunities. ORNL has played a leadership role in the development of a number of initiatives for DOE's Office of Science, such as sitewide Work Smart standards and oversight reduction. This has resulted in opportunities for improvement at all DOE facilities. In addition, the Work Smart standards effort provided the basis for the reengineering of ORNL's ES&H and quality (ESH&Q) functions (see Sect. 5.3.3), which in turn is a key to ORNL's implementation of ISM (see Sect. 5.1.1).

Limits on ES&H funding, continuing emphasis on overhead reduction, and changing relationships with other DOE facilities and contractors in Oak Ridge challenge program continuity and improvements. ORNL works with Lockheed Martin Energy Systems, Inc. (LMES) and Bechtel Jacobs in its efforts to provide an operating environment that supports the accomplishment of mission assignments in a safe, compliant, and cost-effective manner.

5.1.4 • Plans

ORNL's plans for ensuring ES&H compliance are documented in the *FY 2000 Environmental, Safety, Health, Quality, and Infrastructure Budget Formulation Submission for the Oak Ridge National Laboratory* (Lockheed Martin Energy Research Corporation, March 31, 1998) and the ES&H Commitment Affirmation Letter, prepared and submitted in accordance with *ES&H Guidance for FY 2000 Budget Formulation and Execution Commitments Reporting* (Office of Environment, Safety and Health, December 1997). The ORNL budget formulation submission includes a summary of the major ES&H commitments being addressed in the FY 1998 work plan and progress made in meeting those commitments and a

site-level summary of ES&H funding. The commitment affirmation letter summarizes the major ES&H commitments addressed in the FY 1998 work plan and reviews their end-of-year status; it also summarizes the major ES&H commitments in the FY 1999 work plan and significant vulnerabilities that are not entirely eliminated in the FY 1999 work plan.

A Risk Ranking Board, established in FY 1998, ensures that ES&H issues at ORNL receive appropriate attention and consistent funding consideration. The board uses consistent criteria to promote the effective use of resources through risk-knowledgeable operations management. Its work replaces multiple prioritization processes that were often in conflict with established funding mechanisms. The ORNL Risk Ranking Board ranked all ES&H overhead tasks for FY 1998 and FY 1999, ensuring that needs are identified and balanced. The ORNL integrated planning process uses the Board results, thereby ensuring that ES&H considerations are a part of every ORNL project and activity and that consistently prioritized needs are integrated into all decisions.

5.1.5 • Environmental Management Activities

As of April 1, 1998, EM activities at ORNL are managed by Bechtel Jacobs. ORNL's Environmental Management Programs organization and the Office of Environmental Protection in the OES&H Directorate are working with Bechtel Jacobs and DOE-ORO to address the issues and explore the opportunities presented by this change.

5.1.6 • Waste Management Activities

The ORNL Waste Management Operations Division (WMOD) is responsible for the operation, construction, and upgrade of all waste management facilities, with the exception of liquid sanitary waste, at ORNL. WMOD personnel guide ORNL in optimizing its waste reduction and waste management capabilities and carry out waste management operations in a compliant, publicly acceptable, technically sound, and cost-efficient manner.

WMOD operates about 140 facilities at ORNL, including both administrative facilities and facilities for routine treatment of liquid and gaseous radioactive and nonradioactive wastes, long-term storage and surveillance of solid radioactive and mixed wastes, and disposal of radioactive and hazardous wastes. Major activities include strategic planning; development of new or upgraded facilities; and routine waste collection and treatment, storage, and disposal. WMOD provides continuous collection, treatment, and discharge of gaseous wastes; treats 225 million gal per year of liquid radioactive waste (excluding sewage); and manages about 500,000 ft^3 per year of solid wastes.

Programs are in place to implement FFA requirements for active low-level liquid waste (LLLW) tanks and tank systems and to manage ORNL's spent nuclear fuel and transuranic wastes. A program to remediate ORNL's underground petroleum storage tanks to meet Resource Conservation and Recovery Act (RCRA) Subtitle I and Tennessee Department of Environment and Conservation (TDEC) requirements prior to the regulatory deadline of December 1998 is substantially complete.

In 1997, representatives of DOE, ORNL management, WMOD, R&D and support service organizations, and the LMES waste management organization, assisted by industry consultants, conducted a reengineering evaluation of the ORNL waste management program. Their goal, as documented in *Implementation Plan for Waste Management Reengineering at Oak Ridge National Laboratory* (ORNL/TM-13520, October 1997), was to identify ways of

streamlining and improving the waste management process to reduce costs while maintaining full compliance and customer satisfaction.

The plan was approved, and waste management reengineering has been under way for a year. Savings of approximately $8 million have been realized through an improved approach to waste certification and reductions in solid waste generation. Savings of up to $15 million per year were estimated to result from full implementation of the program in FY 1999.

DOE has announced its intention to transfer all waste management activities at ORNL to Bechtel Jacobs under the M&I contract. About 150 waste management workers will be transferred to Bechtel Jacobs in FY 1999. ORNL is working with DOE-ORO and Bechtel Jacobs to establish appropriate mechanisms for addressing this situation.

5.2 • Communication and Trust

5.2.1 • Public Information and Outreach Activities

ORNL supports DOE's commitment to communication and trust and its objective of working with customers and stakeholders in an open, frank, and constructive manner. Considerable effort is invested in increasing public awareness of the Laboratory's programs, functions, successes, lessons learned, and future activities. Programs are in place to address the needs of both the general public and the "internal public"—ORNL employees.

Employee communication vehicles—such as *Ridgelines,* a newsletter for employees and retirees; the "ORNL Today" feature on the internal web server; all-hands meetings; and a system of Laboratory-wide electronic mail—support frequent communication to employees of in-depth information about ORNL programs, projects, policies, and issues.

A media relations program provides information about ORNL activities and their significance to media representatives through the distribution of some 150 news releases per year, through telephone and face-to-face contacts made by ORNL Communications and Public Affairs staff, and through regular updates of ORNL's World Wide Web home page and a special "Newsroom" page. More than 90 examples of positive coverage of ORNL developments or programs in the national or international press were tracked in 1997.

Community outreach and community service programs provide a means for ORNL to demonstrate its commitment to being a good neighbor and a public partner.

- Employees contribute to area agencies through an annual United Way campaign, and many volunteer their time to assist with United Way programs.
- Employees are active in the Friends of the Smokies' grassroots effort to preserve the Great Smoky Mountains National Park.
- Employees support DOE's Oak Ridge EnvironMENTAL Fair, which introduces East Tennessee students to DOE programs, increases their awareness and understanding of environmental issues, and sparks interest in science and technology.
- Employees work to promote and implement successful community partnerships. Significant support has been provided to the East Tennessee Summits and the Clean Cities initiative, and several successful partnerships have been forged with the city of Oak Ridge and other area communities.
- Through business development programs such as the mentor-protégé program and small business partnerships, ORNL shares information and expertise to help entrepreneurs start successful companies.

ORNL also interacts with government leaders and provides them with information about its activities. Initiatives include breakfasts at ORNL for local government officials, tours for members of area "leadership" classes, visits to the state capitol by ORNL leaders, and the provision of news materials to the offices of elected officials. The Laboratory director chairs the State of Tennessee's Science and Technology Advisory Council, which advises the Governor, the General Assembly, and the Commissioner of Economic and Community Development on science and technology issues confronting state government.

ORNL regularly opens its doors to thousands of area residents for Community Day, a full day of tours and festivities celebrating science and its importance to East Tennessee. Some 2,000 people participated in 1997, when ORNL teamed with the city of Oak Ridge, the American Museum of Science and Energy, LMES, and other organizations to sponsor "Oak Ridge Community Day." ORNL also hosts Family Days and Take Your Child to Work Days.

Visitors to ORNL may participate in prearranged general orientation tours, customized group tours, self-guided driving tours, or public bus tours originating at the American Museum of Science and Energy in the city of Oak Ridge. The public bus tours, introduced as a pilot program in 1995, have reached more than 6,000 people. Through the customized tours, some 2,000 students, business people, and technical people visit the Laboratory annually. These tours serve to educate local, regional, and national groups about DOE activities in the Oak Ridge area. They are also expected to help increase science literacy and to serve as a means of obtaining feedback on how ORNL is perceived by the 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. Public education activities at the Oak Ridge National Environmental Research Park include special events, such as wildflower hikes and bird walks, and "hands-on" experiences for precollege students.

DOE has recently transferred the management of the American Museum of Science and Energy to ORNL's scope of work. ORNL will work with DOE and Enterprise Advisory Systems, Inc., which operates the museum under subcontract to LMER, to strengthen public awareness of DOE programs and activities. ORNL also plans to expand communications activities related to the Spallation Neutron Source, broaden its community outreach, and improve the flow of information to its employees.

5.2.2 • Information Resource Management

ORNL is committed to managing and using its technical and administrative information as institutional and multinational assets. 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 ORNL *Strategic Plan for Computing* contains several goals directed toward improved information resource management (IRM). 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 evolving information needs of ORNL;
- maximum participation in deployment of corporate applications to enable appropriate implementation for ORNL;
- efficient records management using electronic retrieval systems; and

- enhanced electronic distribution of documents (i.e., cradle-to-grave electronic publishing and dissemination).

ORNL uses its information management expertise and extensive investments in computing and networking technology to provide a networked information management strategy. The World Wide Web is the interface of choice for global communications about ORNL's research, technology, products, and services and for the Laboratory's internal administrative information and business applications. Web servers are becoming the principal distribution point for information products from ORNL's information centers and databases. Subscriptions to key electronic information sources maximize the availability of information to ORNL's staff.

Core information management and information technology services are provided by the ORNL Computing, Information, and Networking Division. Customer committees work to ensure that these services address the concerns of ORNL staff; these committees include the Administrative Computing Steering Committee, the Scientific Computing User Advisory Committee, the Network Forum, the Internet Technologies Working Group, and the Library Advisory Committee.

5.2.2.1 • Scientific and Technical Information

Scientific and technical information (STI) is a primary product of ORNL's R&D efforts. As a unique national resource, it must be managed wisely throughout its life cycle. Proper management enhances the value of this information as a tool for executing DOE missions and increases its availability to various audiences, including U.S. industry and the public. ORNL is working to increase its electronic delivery of STI to DOE's Office of Scientific and Technical Information.

ORNL is home to one of the most extensive and authoritative complexes of scientific data and information analysis centers in the United States, with several information analysis centers and more than 200 textual and/or numeric databases that cover various technical disciplines in support of DOE and other customers (e.g., the National Aeronautics and Space Administration, the National Oceanic and Atmospheric Administration, the U.S. Environmental Protection Agency, the Department of Health and Human Services). ORNL expects to continue its work to support national needs for scientific and technical information. Programs will be structured to take advantage of emerging information management technologies.

5.2.2.2 • Administrative Information

A single commercial off-the-shelf product, SAP R/3, replaced most of ORNL's core business applications as of October 1, 1998 (see Sect. 5.3.3.2). ORNL continues to improve employee access to information needed in the daily conduct of operations. Web technologies are being applied to increase desktop access to information, with an emphasis on reducing costs and increasing end-user efficiency. The Administrative Computing Steering Committee is the focus for many of these tasks, which include

- using the Web as the preferred interface for forms and business applications;
- supporting Windows, MacOS, and UNIX client platforms;
- evaluating and implementing new applications through the Operational Software Review Board; and
- upgrading operating systems and telecommunications.

The committee also sponsors working groups to address specific initiatives, such as the development of electronic forms and a secure electronic signature process and the reengineering of a process for collecting information on guests, subcontractors, leased personnel, and consultants.

5.2.2.3 • Year 2000 Compliance

ORNL efforts to address computing issues associated with the year 2000 (Y2K) began in 1996 with the appointment of a technical contact to supply information on the remediation of Y2K-impacted software to line organizations, which are responsible for achieving Y2K compliance and meeting all milestones and reporting deadlines. An internal web page, located at <http://www-internal.ornl.gov/cind/Y2K.html>, was established to provide a single source of information for the Laboratory.

Efforts have since expanded to include remediation of hardware, software, and data systems affected by the Y2K problem and planning to manage unmitigated Y2K-related problems (internal and external to ORNL) that arise during the Y2K transition. ORNL has identified more than 200 Y2K-impacted systems and has classified them according to DOE guidance as either mission-essential or non-mission-essential systems. All systems are being tracked for full remediation by March 31, 1999; mission-essential systems are also being tracked on the national level.

A Y2K project team has been formed to manage the increased scope and formality of the effort. The team is responsible for responding to directions from DOE and Lockheed Martin Corporation and for assisting line managers by providing them with technical advice and helping them to fulfill their responsibilities to identify and renovate systems under their control. The project team consists of a project manager and members from the technical, management, legal, and contracts staff. It reports to the Deputy Laboratory Director.

5.3 • Management Practices

5.3.1 • Human Resources

ORNL's Human Resources organization provides consultation and support service to line organizations in several areas: staffing, compensation, personnel relations, employee and organizational development, work force diversity, and consulting and staff support.

Human Resources is reengineering its programs, systems, and processes to support ORNL's overall reengineering efforts (see Sect. 5.3.3.2) and the culture change necessary for these efforts to be successful. Primary goals for Human Resources reengineering are to

1. place responsibility and accountability for human resources transactions at the appropriate individual and organizational levels, thus giving line organizations the authority to make most human resources decisions;
2. let each division or office choose the criteria to best establish and maintain excellence in what it does (one size does not fit all);
3. embrace the role of Human Resources in providing consultation and support to the line organizations; and
4. develop innovative solutions that support the culture change necessary for ORNL to be more effective in performing its assignments and conducting its work faster, cheaper, and better.

A new Human Resources information system, being developed as part of the SAP R/3 implementation (see Sect. 5.3.3.2), will put information and transaction capabilities on the desktop by FY 2000. Revision of human resources policies and procedures to support the desired culture change is under way. Initiatives aimed at supporting the "work force of the future," such as increased flexibility in work schedules and a flexible workplace program to allow "telecommuting" by selected employees, are being implemented. Other key actions are being taken in employee development and rewards and in work force diversity.

5.3.1.1 • Employee Development and Rewards

ORNL works to provide its employees with opportunities to develop and optimize their unique talents and skills and to be rewarded in accordance with their contributions to the success of the business. As part of the cultural change required for successful reengineering, the Laboratory is working to reengineer its performance management system as part of a shift from control of behavior to motivation for performance.

ORNL's performance management process has been streamlined, and line managers are being given new tools to assist them in managing performance, such as a Variable Pay Program that enables them to reward employees who make significant contributions. A competency-based performance management system will be piloted in FY 1999. The system draws on seven underlying job competencies that have been identified, defined, and aligned with ORNL strategies. A new and simplified job worth/job evaluation system will be developed in FY 1999. An integrated employee development module is also planned. The goal is to place the responsibility for most decision making about human relations in the line organizations. Information, tools, and guidelines to support line managers are under development, as are analyses, summary overviews, and reporting of results for senior management review.

"Leadership Alive," a program developed as part of the reengineering effort, is aimed at ensuring ORNL's viability through development of its future leaders. Enhanced succession planning will allow ORNL management to identify employees with the potential to become leaders in the Laboratory and facilitate their development. Customized group workshops, aimed at improving organizational performance, are available to line organizations.

5.3.1.2 • Diversity

ORNL is committed to achieving its strategic business objectives by capitalizing on the diversity of its work force. The Diversity Plan, implemented in March 1996, outlines means for promoting a high-performance, diverse, and inclusive organization. The Diversity Leadership Team, led by the Laboratory deputy director, meets quarterly to monitor progress toward the objectives outlined in the plan.

The ORNL Office of Workforce Diversity annually assesses organizational performance in addressing diversity objectives and reports the results to the Laboratory director. This office also manages an annual awards program that recognizes outstanding efforts toward meeting diversity goals. It has established both internal and external web pages to enhance communications and external benchmarking.

During a period of limited hiring and reductions in the work force, ORNL has continued to emphasize its diversity program. ORNL's reduction in force review process was recognized as a best industry practice by the Nashville office of the Office of Federal Contract Compliance Programs. During the past two years, the overall representation of

women and minorities at ORNL has increased, with the number of women in the Officials and Managers (O&M) category showing a significant increase (from 8.8% to 11.8%). ORNL is committed to increasing the number of minorities in senior O&M and individual contributor positions. Efforts in this area are guided both by the DOE-LMER contract and by metrics associated with the Business Management Review process.

The Office of Workforce Diversity also manages ORNL's Employee Concerns/ Response Program, which is part of an effort to ensure that all employees know that their concerns and suggestions will be taken seriously and feel free to voice them. Key aspects of the Employee Concerns/Response Program are a simple process for submitting suggestions and concerns, a time frame in which the employee's concern should be addressed, and a two-level appeal process.

ORNL will continue working to recruit, retain, and develop a diverse work force; to promote understanding and valuing of differences; and to create an environment that accommodates this future work force. Strategies under consideration include the development of more flexible work schedules, an onsite child care facility and fitness center, and a cafeteria-style benefits package.

5.3.2 • Site and Facilities Management

ORNL is committed to good stewardship of its resources, both in management of existing facilities and in planning for future needs. As described in the *ORNL Land and Facilities Plan* (ORNL/M-6557, August 1998; also available on the World Wide Web at http://www.ornl.gov/~dmsi/landUse/plan.htm), LMER has the management and planning responsibility for ORNL's facilities and for most of the undeveloped land area of the 34,513-acre Oak Ridge Reservation. The Capital Assets Planning Group in the OES&H Directorate carries out capital asset management, facility planning, and space management for ORNL; develops the integrated facilities section of the *ORNL Land and Facilities Plan* and the *ES&H, Quality, and Infrastructure Budget Formulation Submission;* and serves as ORNL's lead organization for DOE's Life-Cycle Asset Management process.

Programs at ORNL require a variety of buildings and equipment, including specialized experimental laboratories, a large complement of office space, and major utility and waste disposal facilities. ORNL has one of the oldest physical plants in the DOE laboratory system, and continuing efforts will be required to renovate and rehabilitate general-purpose buildings and utility systems that have deteriorated owing to insufficient capital improvement funding for modernization and adaptation to changing program needs.

Although funding constraints will continue to limit the amount of work that can be done to remedy this situation, the implementation of recommendations made by the Engineering Design and Construction Reengineering Team (see Sect. 5.3.3.2) is reducing the cost of construction and upgrades. The Risk Ranking Board (see Sect. 5.1.4.2) facilitates a consistent, integrated ranking of Laboratory requirements, as will the planned expansion of a business risk methodology to assess requirements for sitewide utility systems. The development of this integrated process will support the most effective allocation of scarce resources.

5.3.2.1 • Laboratory Description

ORNL's main site encompasses approximately 1,100 acres in the Bethel and Melton valleys, approximately 10 miles southwest of the center of the city of Oak Ridge, Tennessee,

with additional facilities located on the adjacent Copper Ridge. ORNL also occupies space at the Oak Ridge Y-12 Plant and leases some space off site.

As indicated in Table 5.1, buildings at the Melton Valley and Bethel Valley sites and Copper Ridge comprise approximately 3.7 million gross square feet of building space; at the Y-12 Plant, ORNL use accounts for almost 1.4 million gross square feet of building space.

Facilities that have been accepted into the EM program and those that are part of the waste management systems to be managed by Bechtel Jacobs Company under the M&I contract for environmental management have been transferred to Bechtel Jacobs to facilitate the accomplishment of contractual responsibilities. With the exception of these facilities, ORNL has full responsibility for its Bethel Valley and Melton Valley sites and surrounding areas. ORNL is also responsible for management of a 21,076-acre portion of the 34,513-acre Oak Ridge Reservation, including ORNL facilities and most of the 21,500-acre Oak Ridge National Environmental Research Park. At the Y-12 Plant, ORNL has responsibility for building maintenance and ESH&Q functions as approved by Memoranda of Understanding between ORNL and Y-12.

The ORNL site has many functions and requirements similar to those of a small city. It is supported by a dedicated fire department, a medical center, a security force, and a steam plant. Amenities include 37 miles of paved roads, 180 miles of unpaved roads, 27,000 feet of steam lines, 100,000 feet of treated water piping, and 115 acres of mowed grounds.

Replacement plant value is presented in Table 5.2. The overall condition of the space is shown in Fig. 5.1, with use and condition of space in Fig. 5.2 and a summary of building age in Fig. 5.3. Space occupied by ORNL at the Y-12 Plant is not included in Figs. 5.1–5.3. The landlord for the Y-12 Plant is the Department of Energy's Office of Defense Programs.

Table 5.1
ORNL space distribution

	Buildings		Trailers		
Location	Number	Space, ft^2	Number	Space, ft^2	Total space, ft^2
ORNL main site					
LMER	308	3,229,610	58	53,357	3,282,967
Bechtel Jacobs	120	424,842	33	26,918	451,760
Subtotal, ORNL main site	428	3,654,452	91	80,275	3,734,727
ORNL at Y-12	29	1,379,230	2	2,436	1,381,666
Leased off-site	3	62,169	—	—	62,169
Total	**460**	**5,095,851**	**93**	**82,711**	**5,178,562**

Table 5.2
Estimated replacement plant value
(in millions of FY 1997 dollars)

Facility type	Replacement cost
Buildings and structures	3,539
Utility systems	TBD[a]
All other	TBD
Total	TBD

[a]TBD = to be determined.

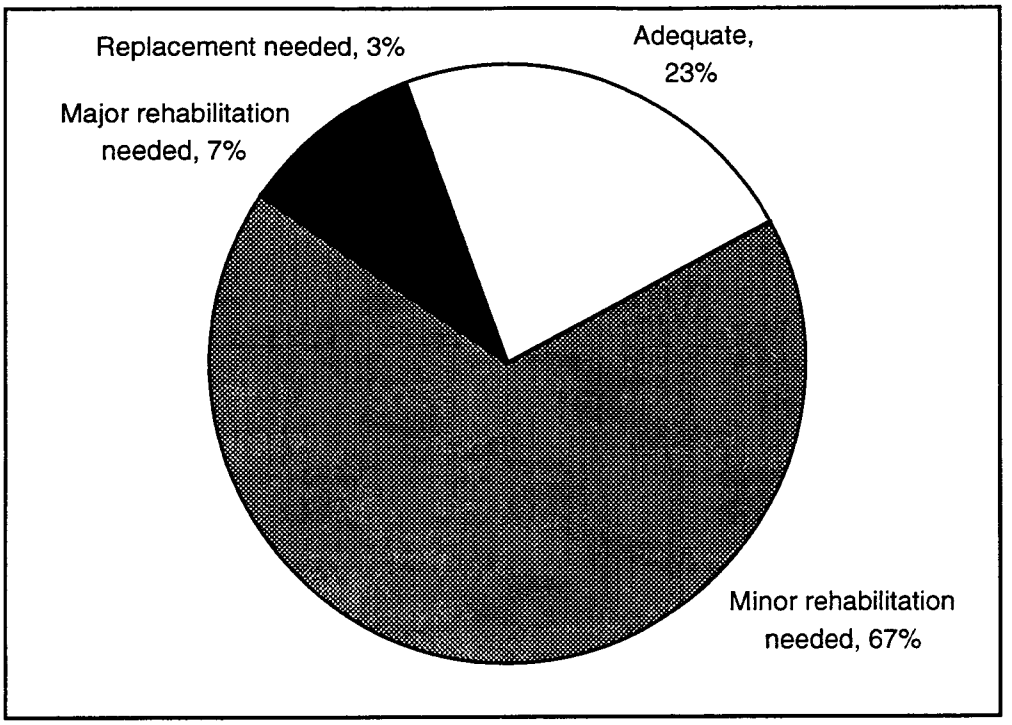


Figure 5.1
Condition of ORNL space, based on cost of modification or repair as a percentage of replacement value. Adequate: cost < 10%. Minor rehabilitation: cost 10%–25%. Major rehabilitation: cost >25%–60%. Replacement: cost > 60%.

5.3.2.2 • Facilities Plans and Options

Facilities plans and options for ORNL are described in the *ORNL Land and Facilities Plan* (ORNL/M-6557, July 1998). The *Environmental, Safety, Health, Quality, and Infrastructure Management Plan for the Oak Ridge National Laboratory* (ORNL/M-6616, November 1998) addresses infrastructure planning, and the *Environmental, Safety, Health, Quality, and Infrastructure Budget Formulation Submission* contains a detailed listing of proposed projects and upgrades and serves as the primary document to support planning and budgeting efforts in this area. The ORNL site planning methodology is shown in Fig. 5.4.

Development Objectives

Development of the ORNL site will focus on providing and maintaining the facilities and infrastructure needed to support ORNL's R&D activities. Existing assets are adequate to fulfill present mission assignments. Significant improvements are needed, however, if ORNL is to meet the five planning objectives presented in the *ORNL Land and Facilities Plan:* compliance, consolidation of activities, adequate working conditions, appropriate visual character, and focused safeguards.

Compliance • ORNL is committed to full compliance with all applicable laws and regulations concerning environmental protection, safety and health, and safeguards and security. Continuing to meet this commitment to full compliance presents a significant challenge. ORNL has been able to meet or exceed the standards set forth in ES&H and safeguards and security regulations, but this has been done by means of "quick fixes" at

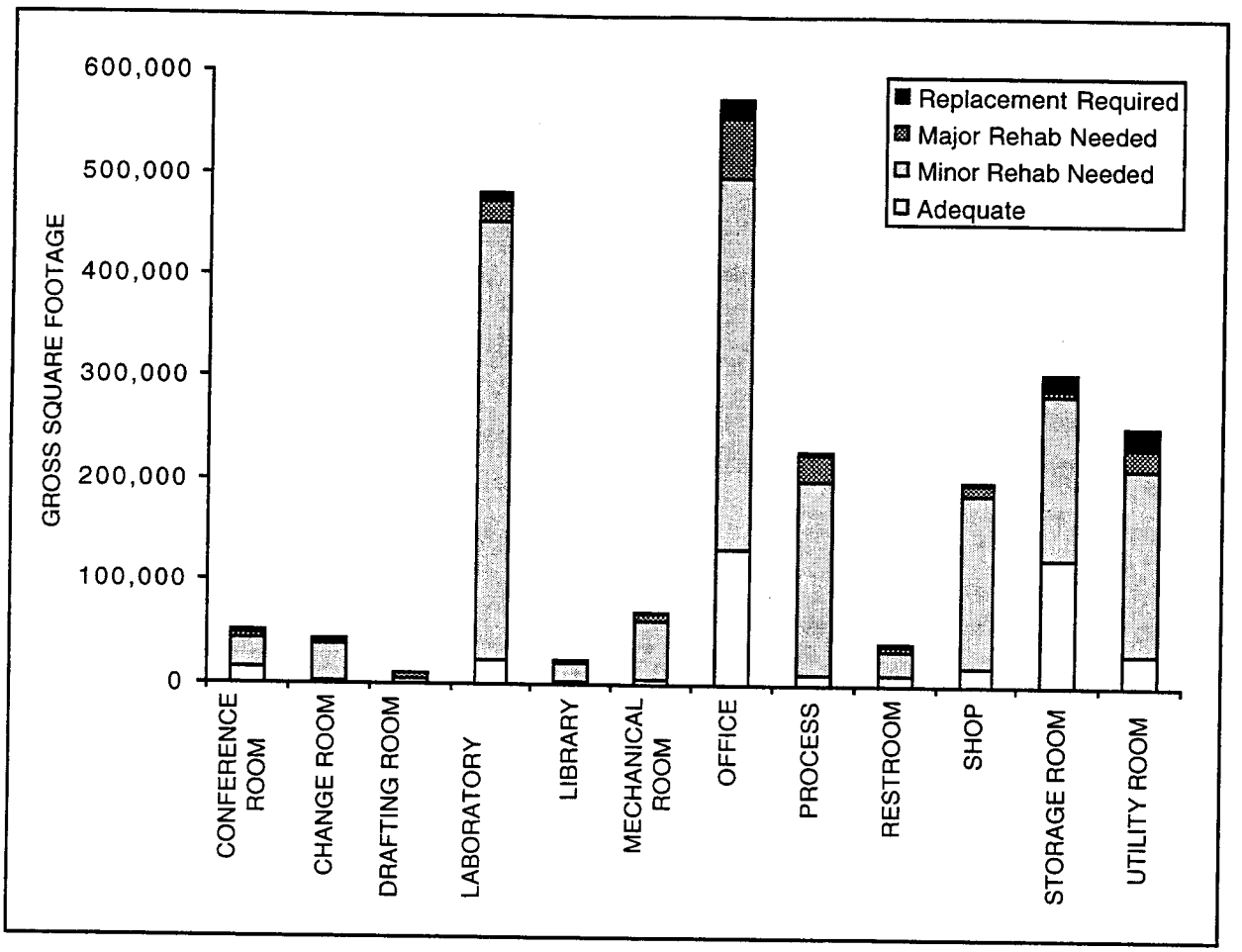


Figure 5.2
Use and condition of ORNL space. Condition is based on cost of modification or repair as a percentage of replacement value. Adequate: cost < 10%. Minor rehabilitation: cost 10%–25%. Major rehabilitation: cost >25%–60%. Replacement: cost > 60%.

increasingly higher costs. ORNL will probably be subject to new regulations as its mission assignments evolve, and aging infrastructure must be replaced or upgraded to meet compliance requirements.

Consolidation of Activities • Only about 72% of ORNL's gross square footage of building space is at the main ORNL site. Another 27% is at the Y-12 Plant, and 1% is leased in the Oak Ridge area. Moreover, the main ORNL site consists of three physically separated areas. As a result, many of ORNL's programs and divisions (and the functions that they perform) are physically dispersed. Consolidation and centralization of these activities into functional, programmatic, or divisional areas is needed to improve the overall operating efficiency of the Laboratory.

Adequate Working Conditions • Steady growth in site population, particularly in the number of visiting researchers and guests, has resulted in overcrowding of facilities, especially offices in the Bethel Valley area, and has required ORNL to make use of temporary buildings, trailers, and off-site rental space. Because of limited budgets, many older facilities (and some newer ones) are in poor condition. Overall, only 23% of ORNL's building space is deemed adequate. While most of the remaining space (approximately 74%

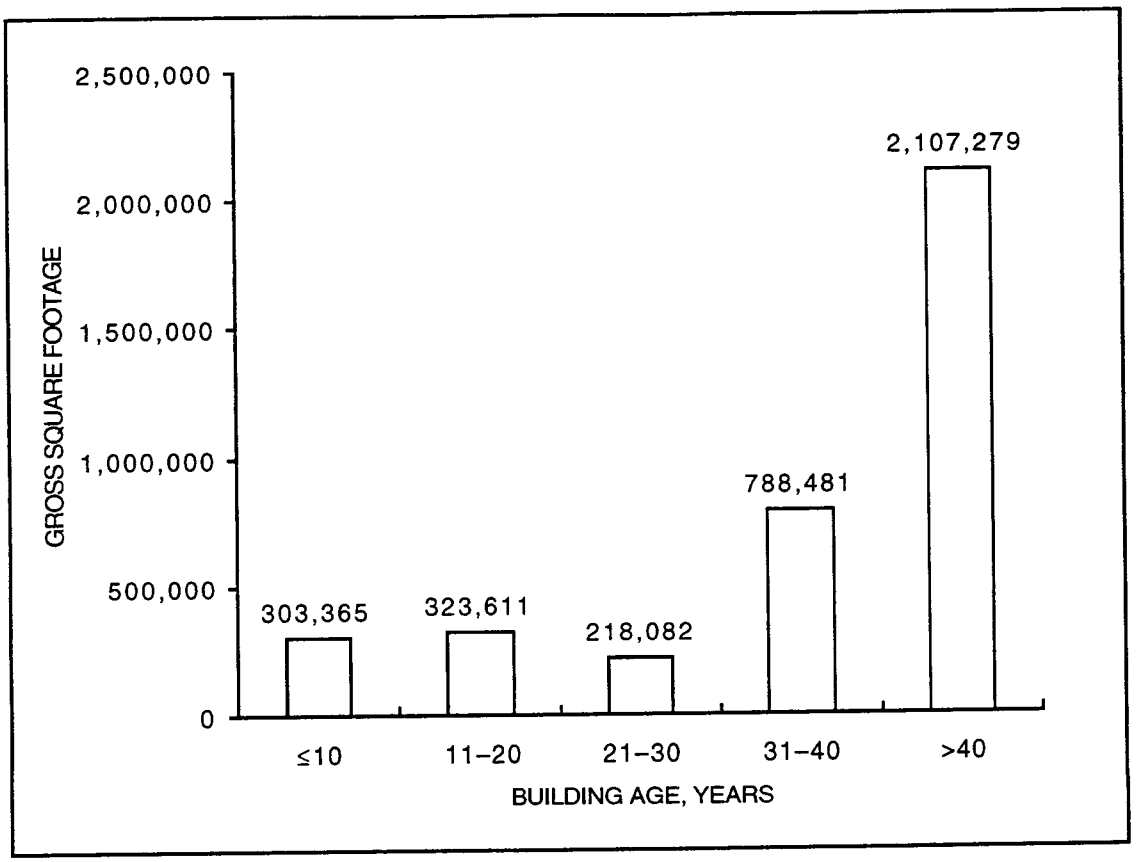


Figure 5.3
Age of ORNL buildings.

of the total) can be rehabilitated, 3% must be replaced. In addition, much of ORNL's infrastructure needs upgrading.

Appropriate Visual Character • A few parts of the main ORNL site have the character of an R&D institution, but much of it resembles a World War II–era industrial site. Creative site development planning and architectural design are needed to take advantage of the beautiful natural setting of the main ORNL site. The atmosphere of a world-class R&D institution should resemble that of a university campus.

Focused Safeguards • Relatively little work that must be shielded or protected for reasons of national security is conducted at the main ORNL site, and portions of the Laboratory operate in areas with security levels beyond current needs. Focusing safeguards and security measures on activities and materials that must be shielded or protected will save money and improve productivity. Security barriers will be configured so that they are a minimal hindrance to the flow of people, material, and equipment throughout the site.

Development Guidelines

Three premises guide land and facilities development:

- The linear pattern of the main ORNL site, which derives from the local ridge and valley terrain, will continue to serve as the general physical form determinant. Areas within Bethel Valley and Melton Valley will be divided into zones of related activity (according to function, program or division). Design will generally resemble that of a university campus.

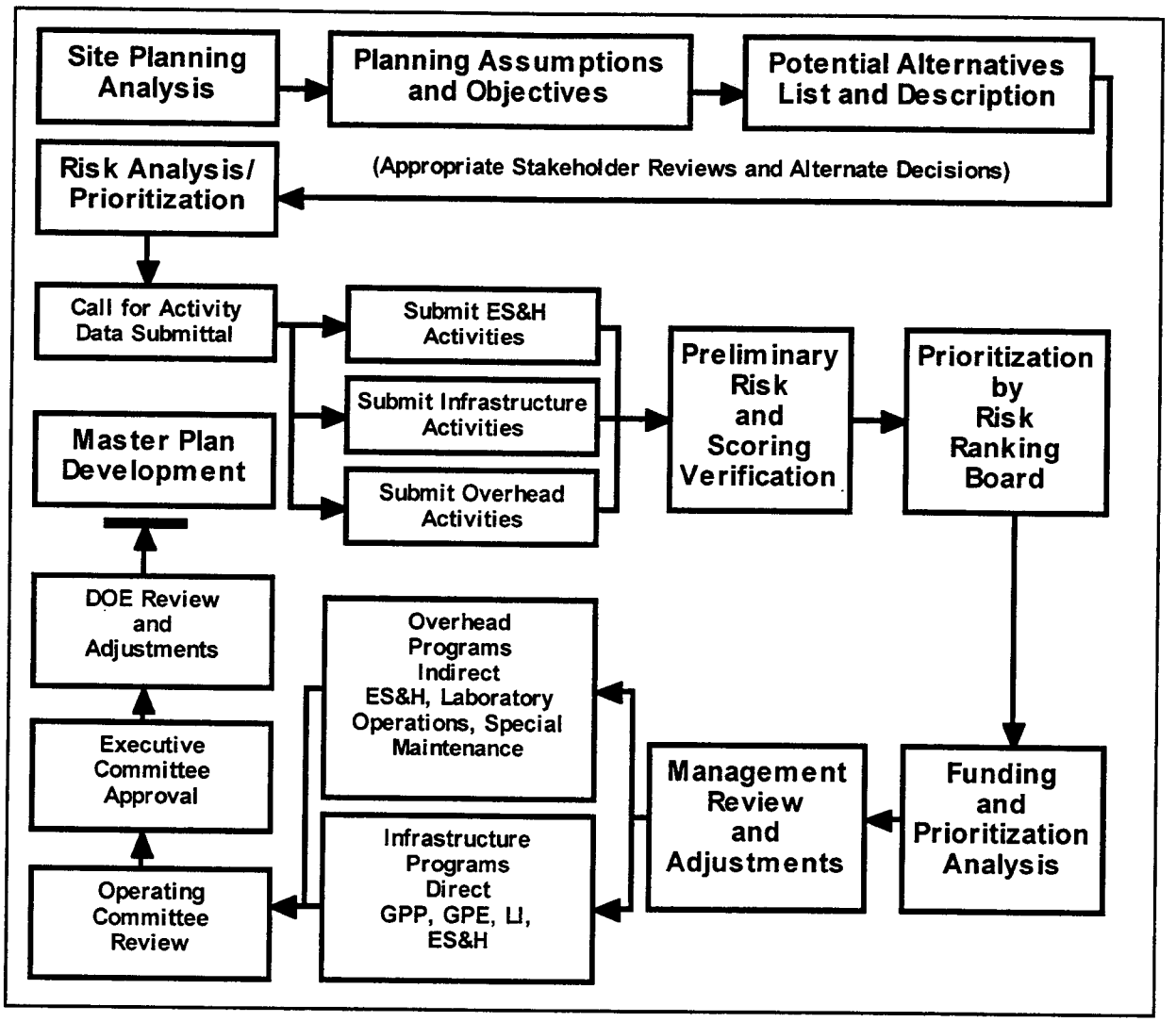


Figure 5.4
ORNL site planning methodology.

- All inadequate or inappropriate facilities at the main ORNL site will eventually be replaced. New facilities will be added to meet mission assignments and requirements.
- ORNL divisions now at the Oak Ridge Y-12 Plant will be relocated in new, purpose-built facilities at the main ORNL site.

In accordance with these guidelines, sections of Bethel Valley east and west of the main ORNL site are identified for future R&D facility use (including support and service facilities). The Bethel Valley area is bordered on the west by Highway 95 and on the east by the Walker Branch Watershed. The Melton Valley and Copper Ridge areas of the ORNL site, from Highway 95 on the west to Melton Hill Lake on the east and south, also provide space for ongoing and projected R&D activities and waste management operations.

The Laboratory's major initiatives, described in Sect. 4, will require the construction of new facilities. In support of the neutron sciences initiative, the Chestnut Ridge area north of the main ORNL complex is the preferred site for the Spallation Neutron Source and for the Joint Institute for Neutron Sciences. The High Flux Isotope Reactor (HFIR) upgrade and refurbishment is under way at the HFIR location in the Melton Valley area. Sites have been identified in the Bethel Valley area for a Laboratory for Comparative and Functional

Genomics to support the functional genomics initiative and for computing facilities to support the distributed computing initiative. As described in Sect. 3.4.2.1, a national radioactive ion beam facility could be constructed in conjunction with the Spallation Neutron Source. A Bethel Valley site has been identified for the Advanced Materials Characterization Laboratory proposed in Sect. 3.4.2.2.

The long-term objective of consolidating at ORNL those activities now located at the Oak Ridge Y-12 Plant is reflected in the identification of Melton Valley locations for an Engineering Technology Complex and a Fusion Materials Irradiation Facility. Areas for future waste operations and facilities are also available in Melton Valley.

5.3.2.3 • General-Purpose Facilities

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. Because ORNL has one of the oldest physical plants in the DOE laboratory system, continuing efforts are needed to enable extensive renovations and rehabilitation of general-purpose buildings and utility systems.

In recent years, ORNL has had to apply general-purpose equipment (GPE) funding to high-priority compliance requirements related to replacement of chlorofluorocarbons (CFCs) and underground storage tanks. These efforts are nearing completion. A GPE-funded program will continue through FY 2001 to replace the remaining CFC chillers and non-CFC chillers that are deteriorated or have excessive leak rates. Appropriate funding is also being sought to replace or repair deteriorating cooling towers.

Upgrades to the steam distribution system are nearing completion, and conversion of the steam plant from coal-fired with gas backup to gas-fired with oil backup has begun, with the addition of a second gas-fired boiler through an FY 1998 line item project. This conversion should be completed by 2004.

Additional funding will be needed to bring buildings and utilities up to acceptable standards and maintain them. General plant projects (GPPs) and line items are planned (see Sect. 5.3.2.5) to upgrade and replace or renovate various infrastructure systems, including electrical, fire protection, heating/ventilation/air conditioning (HVAC), and water systems.

5.3.2.4 • Inactive and Surplus Facilities

About 139 facilities at ORNL sites have been identified as inactive or surplus because the programs for which they were built have ended. Decontamination, demolition, disposal, or renovation will be needed to return land or facilities to ORNL for future use in support of the Laboratory's programmatic activities.

Approximately 72% of these inactive or surplus facilities are process contaminated; 22 facilities are orphaned with no programmatic funding for support. Of the identified facilities, about 100 have been accepted by the Office of Environmental Management (DOE-EM) into either the EM40 program or the EM60 program. These programs manage and ultimately dispose of facilities that have exceeded their useful life and that require continual surveillance and maintenance (S&M) to ensure safe shutdown. Any future funding for facilities accepted into this program of renovation and disposal will be supplied by DOE-EM.

The remaining identified assets are currently surplus or are expected to become surplus beyond FY 1999 because of their lack of mission and a continuing trend of declining

budgets. Furthermore, it is expected that additional ORNL assets will become unusable as a result of obsolescence and deterioration.

Management of ORNL's orphaned and/or inactive and surplus facilities has been subject to limited funding, and funding for future years is uncertain. S&M costs for a facility are generally borne by divisional overhead from the organization that occupies or is responsible for the facility. Opportunities for cost reduction in S&M of these facilities are limited. These facilities have been transferred to the M&I contractor, Bechtel Jacobs, with the requirement that S&M funding for the facilities be transferred as well. This implies a long-term commitment of these funds until final disposition of the facilities is accomplished. Since no direct funding for these activities has been provided, this requirement creates a continuing drain on division and/or Laboratory overhead funding.

The EM40 and EM60 programs are not expected to accept any additional facilities until FY 2002 at the earliest. If no further facilities can be added to the DOE-EM programs, the burden for disposition of surplus and inactive facilities will fall on currently funded programs. This will have a negative impact, both short term and long term, on R&D and/or landlord programs, leading to a decline in research activities and continued infrastructure deterioration.

5.3.2.5 • Facilities Resource Requirements

The management of facility space for the Laboratory presents a number of challenges. ORNL's physical infrastructure, including utilities, will continue to need maintenance and upgrades, both in areas of continuing operation and to maintain unusable facilities in a safe state. Shifts in personnel location and space needs are taking place because of changes in staffing levels associated with the restructuring of DOE's contractual arrangements in the Oak Ridge area and with downsizing and because of Laboratory management's decision to reduce dependence on off-site space.

Several approaches have been implemented to support the effective use of available facility assets. Approximately 22,000 square feet of leased space in the Oak Ridge area has been vacated; personnel and functions formerly located in this space have returned to ORNL sites. ORNL no longer occupies space at the East Tennessee Technology Park. The space chargeback system implemented in April 1998 provides clear incentives for programs and organizations housed in ORNL facilities to efficiently and effectively manage their space.

Constraints on funding for infrastructure requirements and proposed programmatic initiatives make it difficult to address even the most crucial Laboratory needs. The overall emphasis on reducing the federal budget also constrains line-item funding (as well as operational funding) and limits ORNL flexibility in addressing infrastructure and programmatic requirements. Only the most urgent needs can be accommodated under these conditions. For the past three years, GPP and GPE funding has been approximately half of the FY 1995 level. Available funding has been sufficient to meet only a small portion of ORNL's most critical needs.

Requirements in these areas continue to grow, and projected funding levels remain well below the level needed to maintain the Laboratory's infrastructure in good condition. The projected budget for these activities in FY 1999 and FY 2000 is $7.75 million annually. The identified requirements of $13.5 million in FY 1999 and $23.9 million in FY 2000 significantly exceed the available resources. The recent increase in the GPP level from

$2.0 million to $5.0 million makes this situation worse by placing an even larger scope of work, previously funded as line item projects, within the GPP funding program.

To most effectively meet the needs of ORNL programs, GPP and GPE funding needs to be consistent with levels prior to FY 1996. The projected requirements for major facility construction in support of ORNL's vision and missions are included in Tables 5.3 and 5.4.

5.3.2.6 • Asset Management

The Capital Assets Planning Group in the OES&H Directorate is ORNL's lead organization for DOE's Life-Cycle Asset Management (LCAM) process. To support the process, this group prepares the Integrated Facilities Plan (contained in the *Land and Facilities Plan*), which contains technical site information and site development plans and serves as the master plan for future site development, and the *ES&H, Quality, and Infrastructure Budget Formulation Submission,* which serves as the primary document to support planning and budgeting efforts in this area. Execution of the LCAM Implementation Plan is included in ORNL's Critical Outcomes and Performance Objectives (see Sect. 5.3.4).

5.3.3 • Business Management

ORNL's Business Management Organization provides the Laboratory with services in contract administration, finance and budget, procurement, property management, small business programs, Work for Others, and business interfaces with LMES, which formerly held the ORNL management and operating (M&O) contract and continues as the M&O contractor for the Oak Ridge Y-12 Plant. LMES currently provides ORNL with benefits administration and real estate services.

5.3.3.1 • Cost Savings

ORNL continues to seek and implement cost efficiencies as a means of reducing overhead and making more resources available for research. These efforts build on a long-term program of cost reduction that was reinforced by a commitment, made in connection with DOE's Strategic Alignment Initiative, to reduce costs by $18 million per year for five years, beginning in FY 1996. Cost efficiencies arising from reengineering efforts (see Sect. 5.3.3.2), combined with the work of ORNL's Fix-It Committee and individual division efforts, have made it possible for ORNL to meet its $90 million Strategic Alignment Initiative commitment more than two years early.

ORNL also reduced its overhead from $170.6 million in FY 1995 to $152.5 million for FY 1998. During this period, ORNL increased its investments in Laboratory Directed Research and Development (LDRD) funding, reengineering, program development, technology transfer, and the Wigner Postdoctoral Fellows Program. The overhead rate remained essentially constant from FY 1995 through FY 1997 despite these increases in investment funding and during a period when the overhead base dropped significantly. These achievements were accomplished through a cost savings and avoidance program conducted in partnership with the DOE ORNL Site Office. The program includes project promotion and identification, project reporting and validation, and progress reports to the DOE ORNL Site Office and DOE-ORO.

Table 5.3
Major construction projects: funded construction[a]
($ in millions—BA)

	TEC[b]	Fiscal year 1997	1998	1999	2000
Research Program Line Item Projects					
Accelerator and Reactor Improvements and Modifications	9.80	4.50	4.50		
HFIR Cold Source	5.00	2.50			
Spallation Neutron Source	1,333.0			130.0	196.10
EM Program Line Item Projects					
Bethel Valley LLLW-CAT[c] System Upgrade (WBS 3.37)	59.90	1.69			
Bethel Valley FFA Upgrades	13.80	1.11	1.90		
Melton Valley Storage Tanks Capacity Increase	48.00	6.35	1.22		
General Purpose Facility Line Item Projects					
Replace deteriorated roofing	16.00	0.0	3.99	4.91	1.75
Steam plant upgrade (boiler addition)	5.30		3.40	1.90	
General Plant Projects—Landlord					
Environmental and Life Sciences Laboratory	2.20		0.20	2.00	
Fuel oil storage tank	1.00			1.00	
HFIR cooling tower replacement	4.50			0.40	2.40
HFIR User Facility	0.30		0.30		
Neutron Science Support Facility	1.74	0.13	1.56	0.05	
3000-scfm air compressor, Building 2519	1.00		1.00		
Fire protection upgrades	1.25			0.50	0.50
West end steam system	1.82	1.55	0.20	0.07	
Upgrade condensate return system	0.50		0.20	0.30	
Total funded construction	**1,505.11**	**17.83**	**18.47**	**141.13**	**200.75**

[a]Construction data as of January 1999.
[b]TEC = total estimated cost. May include funding from prior years.
[c]LLLW-CAT = low-level liquid waste collection and transfer.

Further cost reductions will be sought in all areas of operations in order to secure a competitive position for ORNL's researchers, provide its organizations with the ability to compete successfully for work from Bechtel Jacobs, and offset the effects of reduced funding in some program areas. Achieving the needed cost reductions will demand innovative thinking in analyzing ORNL's processes, staff involvement in finding improved approaches, and strong leadership to overcome resistance to change.

5.3.3.2 • Reengineering

Laboratory-wide reengineering, which began in 1996 shortly after LMER became ORNL's managing and operating (M&O) contractor, continues with the aim of improving the Laboratory's effectiveness in executing its mission assignments and serving its customers. The formal reengineering effort should be complete during FY 1999, with work continuing through the planning period to improve ORNL's ability to carry out its mission assignments, operate safely and efficiently, and function as a leading research institution.

Table 5.4
Major construction projects: proposed construction[a]
($ in millions—BA)

	TEC[b]	Fiscal year 2000	2001	2002
Research Program Line Item Projects				
HFIR Thermal Neutron Guide Hall	23.6	8.0	15.6	
HFIR Remote Handling Facility	10.0	10.0		
Laboratory for Comparative and Functional Genomics	12.0		8.0	4.0
National Center for Crystal Growth	35.0	0.6	10.0	14.0
General Purpose Facility Line Item Projects				
Computational Sciences Facility	6.7			1.0
Electrical Systems Upgrade	5.9	0.4	5.5	
Fire Protection Systems Upgrade	7.2		2.2	3.0
Laboratory Facilities Ventilation Systems Upgrade	5.5			1.5
Laboratory Facilities HVAC Upgrades	6.9		2.0	3.9
Support Services Facility	6.5			1.5
General Plant Projects—Landlord				
Water Reservoir No. 1 Refurbishment	1.6	1.6		
HVAC upgrades	3.5		2.3	1.2
Water systems upgrade, 1000 area	0.5		0.5	
Transportation and Packaging Facility	3.1		0.5	2.6
Mailroom facility	0.8		0.8	
Upgrade condensate removal system	1.1			1.1
Maintenance shop addition, Building 4509	0.9		0.9	
Building electrical system upgrades	0.9		0.5	0.4
Security perimeter reconfiguration	0.9	0.4	0.5	
HFIR entrance addition	1.0		1.0	
Child care and fitness center	2.0	0.3	1.7	
Replace East End water softener, Steam Plant	0.8		0.8	
Restore natural gas distribution system	1.8		1.8	
Ventilation system upgrade	4.6		2.4	2.2
Facility water system upgrades	2.9		1.9	1.0
Road and parking lot paving	0.9		0.4	0.5
Total proposed construction	**146.6**	**21.3**	**59.3**	**37.9**

[a]Construction data as of January 1999 from Activity Data Sheets.
[b]TEC = total estimated cost.

Reengineering is focusing on several major activities: business systems, engineering design and construction, ESH&Q, human resources (see Sect. 5.3.1), research services, science and technology partnerships (see Sect. 6.1), and waste management (see Sect. 5.1.6). The Reengineering Steering Committee, made up of representatives from each of ORNL's R&D directorates, directs these efforts, routinely reviewing the implementation of recommendations, including the status of each task. Additional processes are brought before the committee and efforts assigned as appropriate.

Business Systems

In partnership with LMES, ORNL is engaged in an ambitious reengineering of its business systems. The Delta Project includes the installation of a commercial off-the-shelf enterprise information system, SAP R/3, to replace a number of existing finance, project management, acquisition, and human resources systems and introduce a number of recognized "best business practices" in these areas. SAP R/3 is a highly integrated information system that will eliminate the need to maintain and update multiple databases and, over the long term, will reduce the costs required to maintain a number of nonintegrated business systems. SAP R/3 "went live" in October 1998, on schedule and within budget. Human resources functionality is to be implemented in FY 1999 and integrated with other SAP business functions.

In parallel with the installation of SAP R/3, new or enhanced automated systems are being used to plan and control cost, reduce redundant systems, and increase efficiency. Examples include the PRISM property management system, which allows equipment custodians and employees to complete most property actions on line, and the Program Management Tracking System, which provides personal computer and workstation users with easy access to programmatic and overhead budget data. These efforts reflect an expansion in ORNL's use of computer networks as a tool for managing and distributing information.

Engineering Design and Construction

Reengineering of engineering design and construction was undertaken with the aim of providing ORNL with cost-effective "industrial standard" engineering and construction support services. The recommendations of the reengineering team are documented in *ORNL Engineering Design and Construction Reengineering Report* (ORNL/TM-13558, Lockheed Martin Energy Research Corp., January 1998).

In January 1997, the ORNL Engineering Division was established from selected elements of the LMES engineering organization and configured to meet the Laboratory's projected needs in the present austere budget climate. Organizational costs have been reduced by 17% compared with 1996.

As recommended by the reengineering team, ORNL has assumed direct responsibility for design contracting and construction management. This approach eliminates several layers of interfaces with the construction management organization, the LMES engineering organization, and DOE. It is expected to save 20 to 30% for a typical construction project.

ORNL has implemented contracting reforms based on commercial contracting requirements, prequalification criteria for construction contractors, and a graded approach to contract specifications using Work Smart standards. These reforms, combined with revisions to ES&H and waste management requirements for roofing projects, have contributed to a significant reduction in the cost of roof replacement. (This reduction was demonstrated before the change in construction management responsibility.)

ORNL is also working with DOE to obtain contracting authority for construction and architect/engineer design services. Several contracts for design are in place. On most jobs, ORNL acts as its own construction manager, hiring construction managers on a project-by-project basis as needed.

The total cost for this reengineering effort was $635,000. Projected savings for the first five projects undertaken with the new approach exceed this amount, and the response

from R&D staff members has been positive. Near-term challenges include working within the Construction Labor Agreement between the Knoxville Building and Construction Trades Council and MK-Ferguson of Oak Ridge and the associated challenge of attracting highly qualified and committed firms to do business at the ORNL site. Another key to achieving cost-effectiveness is adoption of industrial paradigms. The implementation of Work Smart standards is a significant advance toward this end. Efforts are also being made to improve the understanding of the various relationships between costs and requirements and to work with the accounting systems to highlight anomalous practices.

Environment, Safety, Health, and Quality

Reengineering of ESH&Q functions was undertaken to improve ORNL's performance while reducing the cost of compliance activities. DOE's Work Smart standards effort provided the basis for this activity; all ORNL ESH&Q requirements were rewritten to reflect the requirements of the approved Work Smart standards. As a result, the number of procedures was reduced from 103 to 73, all requirements were updated, and copies of procedures are controlled electronically. These changes will result in savings of approximately $1 million annually, thanks to reductions in review requirements and in the cost of maintaining manuals. Compliance training has been consolidated in the OES&H Directorate, and training requirements are reviewed to ensure compliance with the approved standards. The elimination of unnecessary training, the use of innovative training approaches, and the tailoring of requirement to activities has resulted in a 30% reduction in staff training areas.

Reengineering also provided the impetus for the transfer of responsibility for ESH&Q requirements to line organizations. Successful pilot programs in two divisions (Metals and Ceramics, Robotics and Process Systems) provided the basis for the expansion of the pilot program to 50% of ORNL line organizations by the start of FY 1999. This change will align ORNL practices with the best of industrial R&D organizations and is linked to the principles of ISM with its integration of ESH&Q into all facets of ORNL R&D.

Research Support Services

Research support services at ORNL are provided by the Plant and Equipment Division. Reengineering of these services was undertaken with the goal of providing best-in-class services for ORNL. Labor and management are working together in reengineering for improved productivity. A joint labor/management steering team oversees the implementation of reengineering, the director of the Plant and Equipment Division and the bargaining unit representative have a personal partnership agreement, and more than 650 people signed a personal commitment to improve the organizational culture. Measures have been taken to remove barriers to productivity by improving work planning and coordination, procuring newer tools, and ensuring reliable sources of needed materials.

ORNL will continue working to promote the development of a customer focus in its service and support organizations as part of the overall cultural change associated with reengineering. Developing this focus requires continuous emphasis of the need for change, development of appropriate tools and training, and positive recognition of changes when they occur. In addition, the Plant and Equipment Division will be challenged to position itself to support its traditional R&D customer base while also responding to the craft-related needs of M&I-generated work.

5.3.4 • Performance-Based Management

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. A set of Critical Outcomes and Objectives for FY 1999 is under development (see Table 5.5). LMER reports bimonthly achievements toward accomplishment of these Critical Outcomes to DOE-ORO, with an overall assessment report to be provided to DOE-ORO early in FY 2000.

5.3.5 • Quality Programs

The ORNL Office of Quality Services provides quality assurance (QA), quality engineering, and inspection services to support the overall mission of the Laboratory. Specific services include quality planning, quality engineering, inspection, surveillance and verification, performance indicators, administration of the overall Laboratory Assessment Program (which includes audits, issues management, and management of the ORNL Audit Center), and the administration of the Occurrence Reporting, Price Anderson Amendments Act (PAAA) Noncompliance Reporting, and Readiness Review programs.

The Office of Quality Services defines, develops, and assists Laboratory managers in implementing a quality program that fosters effective and efficient accomplishment of ORNL R&D and ES&H objectives and that meets the QA requirements of ORNL's customers. The program incorporates planning for prevention of problems, quality control to assure conformance to requirements, and continuous performance improvement. Independent assessments are conducted to verify compliance with QA requirements and to evaluate the effectiveness of QA programs. Self-assessments are conducted to evaluate performance and identify areas for improvement.

Table 5.5
Critical outcomes for ORNL
(developed by the Oak Ridge Operations Office)

Category	Description
Science	Provide high-quality research and develop leading-edge technologies that are critical to DOE's mission and the nation.
Leadership	Provide leadership that ensures excellence, relevance, and stewardship in all aspects of the conduct of Laboratory operations.
Environment, Safety, and Health	Perform work in a manner that protects the environment and the safety and health of the work force and the public.
Infrastructure	Maintain the infrastructure to support operations in a safe, environmentally responsible, and cost-effective manner.
Business Operations	Use efficient and effective corporate management systems and approaches to guide decision making, streamline and improve operations, align resources and reduce costs, and improve the delivery of products and services.
Stakeholder Relations	Be a good neighbor. Work with customers, stakeholders, and neighbors in an open, frank, and constructive manner.

6 • Enterprise Activities

In support of the missions of the U.S. Department of Energy (DOE), the Oak Ridge National Laboratory (ORNL) develops, maintains, and applies unique, world-leading science and technological facilities and capabilities and collaborates with industry, universities, and other federal laboratories to pursue DOE's missions and to make its capabilities available to others in the national interest. In executing these tasks, ORNL draws on institutional strengths in research and development (R&D) integration and partnerships, development and operation of national research facilities, technology transfer, and science education.

6.1 • Science and Technology Partnerships

ORNL creates partnerships as a means for conducting collaborative R&D, facilitating access to its capabilities, improving utilization of its facilities, transferring technology to industry, and supporting the education of the next generation of scientists and engineers.

As recommended by a Science and Technology Partnerships Reengineering Team chartered as part of the Laboratory's reengineering effort (see Sect. 5.3.3.2), ORNL has established an Office of Partnerships and Program Development. Components of the new organization include the Office of Technology Transfer, the Office of Science and Technology Partnerships (Partnerships Office), and the Work for Others program, as well as ORNL program development staff. Cooperation with Lockheed Martin Energy Systems, Inc. (LMES) organizations is a key element; the deputy director of the LMES National Security Programs Office and the ORNL co-director of the Oak Ridge Centers for Manufacturing Technology (ORCMT) are also assigned to the Office of Partnerships and Program Development. Educational activities (see Sect. 6.1.4) are coordinated through the ORNL Office of University and Science Education.

6.1.1 • Collaborative Relationships

As the only national laboratory in the southeastern United States, ORNL places a strong emphasis on building collaborative relationships in this region, particularly with the University of Tennessee (UT). Other regional partners include the Tennessee Valley Authority, the Oak Ridge Institute for Science and Education, historically black colleges and universities (HBCUs), and area primary and secondary schools. Many of the companies that access ORNL resources through the ORCMT, a cooperative effort of ORNL and the Oak Ridge Y-12 Plant, are located in the southeastern United States.

ORNL will continue to develop and draw on collaborative relationships that support DOE's missions. In particular, ORNL plans to increase its outreach to small and

medium-sized businesses, focusing on increasing awareness of cooperative research and technical assistance opportunities available to these firms. These businesses are also good candidates for partnerships under the Small Business Technology Transfer (STTR) Program.

A major effort is aimed at building new educational, training, and research partnerships with other federal agencies; with schools, colleges, and universities; with educational consortia and museums, both regionally and nationally; and with private-sector institutions.

6.1.1.1 • Laboratory Partnerships

ORNL actively supports the "System of Labs" concept and is engaged in numerous collaborative relationships with other national laboratories. Most notable is the Spallation Neutron Source (SNS) collaboration with Argonne, Brookhaven, Lawrence Berkeley, and Los Alamos (see Sect. 4.1.1). Other DOE-sponsored collaborations include

- the National Spherical Torus Experiment, a joint project with the Princeton Plasma Physics Laboratory (PPPL), Columbia University, and the University of Washington;
- the PHENIX detector for the Relativistic Heavy Ion Collider at Brookhaven;
- the Main Injector Neutrino Oscillation Search (MINOS) experiment at the Fermi National Accelerator Laboratory;
- the Materials Microcharacterization Collaboratory, which provides on-line access to materials science research capabilities, with Argonne, Lawrence Berkeley, the National Institute for Standards and Technology, and the University of Illinois;
- the Genome Annotation Consortium, through which ORNL is working with Argonne, Lawrence Berkeley, Livermore, Los Alamos, several universities, and other research institutions to provide a comprehensive sequence-based view of genomes;
- the High-Performance Storage System development project, which links Livermore, Los Alamos, Sandia, and ORNL with industrial partners;
- the DOE 2000 initiative, sponsored by the Office of Computational and Technology Research within the DOE Office of Energy Research, which is creating and applying computational tools and libraries that advance the concept of "national collaboratories";
- the Energy Efficiency and Renewable Energy Network with Argonne and the National Renewable Energy Laboratory;
- an ORNL-Sandia-Idaho collaboration, initiated through Laboratory Directed R&D funds from each laboratory, that integrates unique capabilities in the development of the Laser-Assisted Arc Welding (LAAW) process; and
- the Interlaboratory Task Force on Unexploded Ordnance, which coordinates the capabilities of 11 DOE laboratories and facilities (see Sect. 3.4.4.3).

6.1.1.2 • University Partnerships

ORNL is involved in a number of research partnerships with universities, most of which also have a strong education component. Academic outreach is also reflected in subcontracted R&D with university partners, which represents about $20 million annually.

The Laboratory is building relationships with Tennessee's Centers of Excellence program for public higher education. This program supports 26 Centers of Excellence and a number of Chairs of Excellence, held by outstanding professors, at Tennessee Board of Regents institutions (6 universities, 14 two-year colleges, and 26 technology centers) and the UT campuses. Their purpose is to expand the state's research base, with the aim of increasing Tennessee's national and international stature and its economic competitiveness.

ORNL and UT are partners in the Science Alliance, the state's oldest and largest academic Center of Excellence. The Science Alliance sponsors the ORNL-UT Distinguished Scientist Program, which provides joint appointments to tenured positions at UT Knoxville and research positions at ORNL. Graduate programs and joint institutes in biological sciences, computational sciences, energy and environment, and neutron sciences represent additional tools for combining the resources of these institutions for research and education. The National Transportation Research Center and the National Safe Skies Alliance, described in Sect. 3.4.4.2, are providing new opportunities for collaboration.

ORNL has recently signed a Memorandum of Cooperation with UT, Vanderbilt University Medical Center, St. Jude Children's Research Hospital, and Meharry Medical College (an HBCU) for collaborative research in developing mouse models for human diseases. This arrangement is the result of an initiative undertaken through the Joint Institute for Biological Sciences (see Sect. 4.2.3).

ORNL interacts extensively with HBCUs and minority educational institutions (MEIs) through mechanisms such as the DOE Science and Technology Alliance, the Waste Management Consortium, the National Consortium for Graduate Degrees for Minorities in Engineering, Inc. (GEM Consortium), the Consorcio Educativo para la Proteccion Ambiental (CEPA), and the Advanced Industrial Concepts Materials Fellowship Program. ORNL also administers 13 subcontracts with HBCUs and MEIs, representing funding of $2,531, 232 in FY 1998.

6.1.1.3 • Industry Partnerships

ORNL supports DOE's efforts to advance the nation's economic security by leveraging industrial and government resources to address industrial problems and by encouraging more effective use of the DOE facilities by external groups.

The ORNL Small Business Program Office serves as the focal point for projects involving minority businesses. For example, DOE's Mentor-Protégé Program provides a mechanism for contractors to enter into integrated working relationships with and provide nonfinancial assistance to energy-related small, disadvantaged, and women-owned businesses to enhance their business and technical capabilities. In February 1998, ORNL became the first DOE national laboratory to participate in this program by signing a mentor-protégé agreement with Advanced Integrated Management Services, Inc. (AIMSI). Under the terms of the agreement, ORNL will mentor AIMSI during the next two years in a number of areas. Subcontracting activities will be provided by ORNL's Chemical Technology and Engineering divisions for project management support. Training will be provided as needed to enhance and strengthen AIMSI's technical and business capabilities.

The Partnerships Office is also working to encourage more interaction with small businesses. Much of this activity is expected to occur in the technical assistance area, with support from the Laboratory Technology Research assistance program. During the first two months of this new program, ORNL assisted ten small businesses.

Cooperative partnerships with industry continue to be an attractive mechanism for affording access to ORNL's scientific resources and skills. Furthermore, the leveraging of research dollars through cost sharing is beneficial to both parties. As of September 30, 1998, ORNL's cumulative total for CRADAs was 259 (not including joint ORNL/Y-12 projects), representing commitments of more than $500 million split approximately half and half between federal monies and the private sector.

The American Textile Partnership (AMTEX), a collaborative program involving ten DOE laboratories and the U.S. textile industry, is engaging the technical capabilities of the laboratories in developing and deploying technologies that will increase the competitiveness of this industry. The Partnership for a New Generation of Vehicles (PNGV) also presents opportunities for cooperative projects that involve programs in DOE's Offices of Energy Research, Energy Efficiency and Renewable Energy (DOE-EE), and Defense Programs. ORNL is pursuing the implementation of partnerships with companies and consortia representing the seven primary manufacturing industries and the agriculture industry as part of the Industries of the Future initiative sponsored by DOE-EE.

6.1.2 • Guests and Users

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 goals in scientific cooperation and technology transfer. In FY 1997, the Partnership Office supported more than 3500 assignments of scientists and engineers from universities, industries, and other federal institutions. About 25% were industrial guests. Many of these guests carry out R&D at one of ORNL's designated user facilities.

6.1.3 • Technology Transfer

Through the Office of Partnerships and Program Development, ORNL works with other DOE facilities in Oak Ridge to enable private industry and academia to make practical application of the advanced R&D and technical expertise from these facilities.

The Office of Technology Transfer continues to promote the licensing of new technologies and the effective management of intellectual property. In FY 1998, 53 patents were issued (up from 43 in FY 1997) and 33 licenses were executed (up from 31 in FY 1997).

6.1.4 • Science Education

ORNL actively supports scientific and technological education by engaging students and faculty at all academic levels in research, interaction, and collaboration. The Office of University and Science Education coordinates the Laboratory's mathematics and science education activities.

ORNL-sponsored educational outreach and research participation programs seek to (1) improve the quality of science and mathematics teaching and learning, (2) increase the size and diversity of the educational pipeline, and (3) ensure the future availability of required scientific and technical skills. The focus is on inquiry-based, "hands-on" learning and research experiences, complementing that of degree-granting institutions and providing access to resources that are unavailable at many schools and universities.

Science education programs make extensive use of partnerships with a wide variety of other organizations. For example, the Office of University and Science Education and the ORNL Energy Division recently received a grant from the U.S. Department of Education to develop Internet-based learning materials. The project brings teachers from Tennessee, Virginia, South Carolina, and New York to ORNL to participate in the development and testing of an Internet tutorial about energy. The annual summer SciCops camp, conducted in collaboration with the Knox County Sheriff's Department, introduces middle-school students

to the role of science in law enforcement. ORNL works with the Appalachian Regional Commission to offer a Summer Science Honors Academy and a Teacher Leadership Institute to students and teachers from Appalachian states.

During the planning period, ORNL will continue to seek opportunities to apply its resources to educating the next generation of scientists and engineers and to improving scientific and technological literacy. The recent addition of the American Museum of Science and Energy to ORNL's statement of work (see Sect. 5.2.1) will provide new opportunities in these areas.

6.2 • Developing Strengths for Mission Needs

6.2.1 • Laboratory Directed R&D

The Laboratory Directed R&D (LDRD) Program described in Sect. 2.3.3.7 provides a means of funding activities that are expected to enhance ORNL's capabilities for carrying out DOE missions. In requesting proposals for FY 1999 LDRD funds, the Laboratory's senior managers emphasized two research areas: Laboratory Technical Foundations and Functional Genomics. In the Laboratory Technical Foundations area, research topics organized according to the six areas of R&D emphasis described in Sect. 2.3.1 were selected by the Laboratory's senior managers to encourage and foster innovative R&D in these priority areas. The Functional Genomics area supports the major initiative (see Sect. 4.2) to leverage ORNL's outstanding expertise and facilities in mammalian genetics, plant genetics, bioinformatics and computational biology, biochemistry, and environmental microbiology and its resources for cutting-edge technology development to accelerate the exploration of gene function.

6.2.1.1 • Laboratory Technical Foundations

In support of the Laboratory's distinctive capabilities, up to $3 million in LDRD funds is to be awarded for innovative projects in selected research areas, grouped by ORNL's six areas of R&D emphasis.

- Advanced materials synthesis, processing, and characterization
  - Biomaterials/biomimetics and soft condensed matter
  - Nanoscale materials, nanostructured composites, and nanofabrication
  - Smart materials
- Biological and environmental sciences and technology
  - Analyses of complex biological systems
  - Carbon management (analyses, environmental systems research, bioprocessing, separations science)
  - Genomics applications to plants and microbes
- Computational science and advanced computing
  - Combustion modeling
  - Global change modeling

- Energy production and end-use technologies
  - Energy conservation, energy efficiency, and renewables
  - Greenhouse gas reduction technologies (novel separations technologies, bioprocessing, and other remediation and sequestration strategies)
- Instrumentation and measurement science and technology
  - Applications to biological and environmental systems and chemical processes
  - Novel biological and chemical detection and measurement
- Neutron-based science and technology
  - Novel approaches to pulsed-source-based science and experimental techniques

6.2.1.2 • Functional Genomics

In support of the major Laboratory initiative in functional genomics, $2 million of FY 1999 LDRD funding is earmarked for new projects in this area. The third year of this program will build on the accomplishments of the first two through the development of innovative strategies for gene function research. Areas of particular interest include

- development of innovative procedures for comparative analyses of mouse, human, microbial, plant, and other genomes for the purpose of identifying genes and regulatory elements on the DNA;
- analysis of the expression of gene products (RNA and/or proteins), by such means as measuring steady-state levels of gene products in a given cell type, measuring temporal or induced changes in patterns of gene product levels, or measuring comparative levels of gene products in different cell types;
- analysis of the biological role that gene products play within the cell (e.g., analysis of cellular localization of proteins, protein-protein or protein-nucleic acid interactions or comparative analysis of protein sequences and/or structures); and
- development of innovative procedures for efficiently studying multigenic traits in mice.

6.2.2 • Program Development Activities

Program development activities at ORNL are focused on maintaining the R&D expertise available to DOE and on identifying and pursuing new opportunities to apply the Laboratory's strengths to mission-related needs. During the planning period, increasing emphasis will be placed on opportunities in emerging areas, such as gene function and biotechnology, and areas in which pressing national needs exist, such as transportation and environmental protection. These activities serve to broaden ORNL's customer base and provide opportunities for partnerships with universities, industry, other DOE laboratories, other federal agencies, and state and regional organizations.

As noted in Sect. 6.1, ORNL has recently created an Office of Partnerships and Program Development to facilitate productive interactions with partners. The organization coordinates activities related to the development of new programs and manages key services dealing with intellectual property and partnerships. ORNL also plans to continue its emphasis on offsite assignments of staff members, which provide opportunities for integration of ORNL staff into other government agencies and for learning more about the private sector.

7 • Resource Projections

Resource projections are presented in the following tables:

- Table 7.1, Laboratory funding summary,
- Table 7.2, Laboratory personnel summary,
- Table 7.3, funding by assistant secretarial level office, and
- Table 7.4, personnel by assistant secretarial level office.

These projections are based on funding requested in the FY 1999 budget submission documents, with some adjustments for subsequent guidance. They include some funding for construction that supports the major laboratory initiatives proposed in Sect. 4.

In Tables 7.1 and 7.3, resource projections for future years are presented in terms of new budget authority (BA) funding in millions of dollars. New BA requests are calculated by adding estimates of fiscal year-end outstanding commitments (institutional, programmatic, and continued operation) to the total cost and then subtracting the prior-year uncosted budget.

Personnel projections in Tables 7.2 and 7.4 are given as the number of full-time equivalent (FTE) employees.

Table 7.1
Laboratory funding summary by fiscal year
($ in millions—BA)

	1997	1998	1999	2000	2001	2002	2003
DOE effort	432.6	477.7	426.1	393.7	383.2	374.4	373.4
Work for others	84.5	85.2	71.8	86.1	91.7	93.3	94.9
Total operating	517.1	562.9	497.9	479.8	474.9	467.7	468.3
Capital equipment	8.4	11.8	15.3	15.5	12.7	13.0	5.8
General Plant Equipment (GPE)	4.3	4.3	4.7	0.0	0.0	0.0	0.0
Construction	7.6	3.7	2.0	2.0	2.0	0.0	0.0
Total ORNL	537.4	582.7	519.9	497.3	489.6	480.7	474.1
Proposed construction	—	9.1	141.0	225.3	289.9	264.4	192.6
Total projected funding	—	591.8	660.9	722.6	779.5	745.1	666.7

Table 7.2
Laboratory personnel summary by fiscal year
[Full-time equivalent (FTE) employees]

	1997	1998	1999	2000	2001	2002	2003
Technical personnel, direct DOE effort	1105.0	1098.1	1265.8	1179.3	1153.8	1141.0	1141.0
Technical personnel, Work for Others	258.5	259.1	300.6	354.7	345.4	345.4	345.4
Total technical direct personnel	1363.5	1357.2	1566.4	1534.0	1499.2	1486.4	1486.4
Other direct	717.2	662.0	624.7	582.3	555.8	542.5	542.5
Total direct personnel	2080.7	2019.2	2191.1	2116.3	2055.0	2028.9	2028.9
Indirect personnel (estimated)	2339.3	2300.0	2100.0	2000.0	2000.0	2000.0	1950.0
Total ORNL personnel	4420.0	4319.2	4291.1	4116.3	4055.0	4028.9	4028.9

Table 7.3
Funding by assistant secretarial level office by fiscal year
($ in millions—BA)

	1997	1998	1999	2000	2001	2002	2003
Science and Technology Programs							
Office of Science							
Operating expense	143.2	170.1	167.3	170.5	162.4	157.7	158.1
Capital equipment	7.7	8.9	13.4	12.6	10.8	11.0	4.3
General Plant Equipment (GPE)	4.3	4.3	4.7	0.0	0.0	0.0	0.0
Construction	5.9	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction	0.1	9.1	141.0	225.3	289.9	264.4	192.6
Total	161.2	192.4	326.4	408.4	463.1	433.1	355.0
Energy Programs							
Office of Energy Efficiency and Renewable Energy							
Operating expense	66.3	86.0	89.7	94.8	97.6	100.5	100.5
Capital equipment	0.4	0.7	0.8	0.8	0.8	0.8	0.8
Construction	0.0	0.8	0.0	0.0	0.0	0.0	0.0
Total	66.7	87.5	90.5	95.6	98.4	101.3	101.3
Office of Nuclear Energy, Science and Technology							
Operating expense	23.4	15.0	17.9	19.3	20.8	21.8	21.8
Capital equipment	0.1	0.0	0.2	0.2	0.2	0.2	0.2
Total	23.5	15.0	18.1	19.5	21.0	22.0	22.0
Office of Fossil Energy							
Operating expense	7.4	8.2	11.7	11.3	12.0	12.0	12.0
Energy Information Administration							
Operating expense	0.0	0.0	0.0	0.0	0.0	0.0	0.0
National Security Programs							
Office of Defense Programs							
Operating expense	11.7	17.4	19.4	18.9	18.8	18.8	18.8
Capital equipment	0.0	0.0	0.5	1.5	0.5	0.5	0.0
Construction	1.6	1.5	2.0	2.0	2.0	0.0	0.0
Total	13.3	18.9	21.9	22.4	21.3	19.3	18.8
Office of Nonproliferation and National Security							
Operating expense	0.1	0.0	0.1	0.1	0.1	0.1	0.1
Office of Fissile Materials Disposition							
Operating expense	10.6	13.7	10.5	13.0	12.0	14.0	12.0
Environmental Management Programs							
Office of Environmental Management[a]							
Operating expense	0.0	33.1	26.0	17.9	14.9	14.9	14.9
Office of Civilian Radioactive Waste Management							
Operating expense	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Office of Environment, Safety, and Health							
Operating expense	8.3	6.4	6.8	6.7	6.7	6.7	6.7

Table 7.3
(continued)

	1997	1998	1999	2000	2001	2002	2003
Other DOE Programs							
Office of Policy and International Affairs							
Operating expense	0.7	0.5	0.4	0.4	0.4	0.4	0.4
Federal Energy Regulatory Commission							
Operating expense	0.2	1.4	0.5	0.5	0.6	0.1	0.1
EM funding from LMES central financial plan and Bechtel Jacobs Co.							
Operating expense	139.6	113.3	47.1	22.1	18.1	8.0	8.0
Capital equipment	0.0	1.6	0.4	0.4	0.4	0.5	0.5
Construction	0.1	1.4	0.0	0.0	0.0	0.0	0.0
Total	139.7	116.3	47.5	22.5	18.5	8.5	8.5
Subtotal DOE Programs							
Operating expense	411.5	465.1	397.4	375.6	364.5	355.1	353.5
Capital equipment	8.2	11.2	15.3	15.5	12.7	13.0	5.8
General Plant Equipment (GPE)	4.3	4.3	4.7	0.0	0.0	0.0	0.0
Construction	7.6	3.7	2.0	2.0	2.0	0.0	0.0
Proposed construction	0.1	9.1	141.0	225.3	289.9	264.4	192.6
Total	431.7	493.4	560.4	618.4	669.1	632.5	551.9
DOE Contractors and Operations Offices							
Operating expense	18.9	10.8	28.0	17.0	17.5	18.0	18.5
Capital equipment	0.2	0.1	0.0	0.0	0.0	0.0	0.0
Total	19.1	10.9	28.0	17.0	17.5	18.0	18.5
Cooperative R&D Agreements							
Operating expense	2.2	1.8	0.7	1.1	1.2	1.3	1.4
Total DOE Programs							
Operating expense	432.6	477.7	426.1	393.7	383.2	374.4	373.4
Capital equipment	8.4	11.3	15.3	15.5	12.7	13.0	5.8
General Plant Equipment (GPE)	4.3	4.3	4.7	0.0	0.0	0.0	0.0
Construction	7.6	3.7	2.0	2.0	2.0	0.0	0.0
Proposed construction	0.0	9.1	141.0	225.3	289.9	264.4	192.6
Total	452.9	506.1	589.1	636.5	687.8	651.8	571.8
Work for others							
Nuclear Regulatory Commission							
Operating expense	13.3	10.8	10.8	13.0	13.0	13.0	13.0
Department of Defense							
Operating expense	25.2	26.0	27.0	28.0	30.0	32.0	32.0
Capital equipment	0.0	0.5	0.0	0.0	0.0	0.0	0.0
Total	25.2	26.5	27.0	28.0	30.0	32.0	32.0
National Aeronautics and Space Administration							
Operating expense	2.9	4.7	5.0	5.1	5.1	5.1	5.1
Department of Health and Human Services							
Operating expense	0.7	2.4	2.4	1.9	1.9	1.9	1.9

Table 7.3
(continued)

	1997	1998	1999	2000	2001	2002	2003
Environmental Protection Agency							
Operating expense	3.7	5.1	3.7	3.6	3.6	3.6	3.6
National Science Foundation							
Operating expense	1.2	0.2	0.1	0.0	0.0	0.0	0.0
Federal Emergency Management Agency							
Operating expense	0.7	3.1	3.0	1.5	1.5	1.5	1.5
Department of Transportation							
Operating expense	1.1	3.2	3.2	9.5	9.5	9.5	9.5
Other Federal agencies							
Operating expense	19.1	12.6	12.0	13.6	16.2	15.3	16.9
Electric Power Research Institute							
Operating expense	1.6	1.1	1.0	0.9	0.9	0.9	0.9
Other nonfederal agencies							
Operating expense	15.0	16.0	3.6	8.9	9.9	10.4	10.4
Total Work for Others							
Operating expense	84.5	85.2	71.8	86.1	91.7	93.3	94.9
Capital equipment	0.0	0.5	0.0	0.0	0.0	0.0	0.0
Total	84.5	85.7	71.8	86.1	91.7	93.3	94.9
Total ORNL							
Operating expense	517.1	562.9	497.9	479.8	474.9	467.7	468.3
Capital equipment	8.4	11.8	15.3	15.5	12.7	13.0	5.8
General Plant Equipment (GPE)	4.3	4.3	4.7	0.0	0.0	0.0	0.0
Construction	7.6	3.7	2.0	2.0	2.0	0.0	0.0
Proposed construction	0.0	9.1	141.0	225.3	289.9	264.4	192.6
Total	537.4	591.8	660.9	722.6	779.5	745.1	666.7

[a]Prior to March 31, 1998, Environmental Management budgets were carried in the Central Financial Plan for Lockheed Martin Energy Systems, Inc.

Table 7.4

Personnel by assistant secretarial level office by fiscal year

[Full-time equivalent (FTE) employees]

	1997	1998	1999	2000	2001	2002	2003
Office of Science							
Technical personnel	480.1	477.6	611.7	596.0	596.0	596.0	596.0
Other direct personnel	164.4	171.9	272.9	306.1	306.1	306.1	306.1
Total direct personnel	644.5	649.5	884.6	902.1	902.1	902.1	902.1
Office of Energy Efficiency and Renewable Energy							
Technical personnel	185.4	196.7	208.5	205.1	205.1	205.1	205.1
Other direct personnel	50.7	55.1	31.9	32.8	32.8	32.8	32.8
Total direct personnel	236.1	251.8	240.4	237.9	237.9	237.9	237.9
Office of Nuclear Energy, Science and Technology							
Technical personnel	47.7	51.0	94.5	94.5	94.5	94.5	94.5
Other direct personnel	39.0	36.7	30.4	31.5	31.5	31.5	31.5
Total direct personnel	86.7	87.7	124.9	126.0	126.0	126.0	126.0
Office of Fossil Energy							
Technical personnel	15.5	19.9	22.6	22.5	22.5	22.5	22.5
Other direct personnel	3.8	6.1	2.5	2.9	2.9	2.9	2.9
Total direct personnel	19.3	26.0	25.1	25.4	25.4	25.4	25.4
Energy Information Administration							
Technical personnel	0.2	0.0	0.2	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
Total direct personnel	0.2	0.1	0.2	2.0	2.0	2.0	2.0
Office of Defense Programs							
Technical personnel	34.4	46.9	64.5	57.0	57.0	57.0	57.0
Other direct personnel	22.2	25.2	42.4	48.1	48.1	48.1	48.1
Total direct personnel	56.6	72.1	106.9	105.1	105.1	105.1	105.1
Office of Nonproliferation and National Security							
Technical personnel	0.1	0.0	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
Total direct personnel	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Office of Fissile Materials Disposition							
Technical personnel	27.9	36.1	43.4	51.5	51.5	51.5	51.5
Other direct personnel	8.6	10.4	14.5	17.9	17.9	17.9	17.9
Total direct personnel	36.5	46.5	57.9	69.4	69.4	69.4	69.4
Office of Environmental Management							
Technical personnel	0.0	74.3	68.3	40.8	40.9	40.9	40.9
Other direct personnel	0.0	14.9	80.9	46.0	46.0	46.0	46.0
Total direct personnel	0.0	89.2	149.2	86.8	86.9	86.9	86.9
Office of Civilian Radioactive Waste Management							
Technical personnel	0.1	0.1	0.9	0.4	0.4	0.4	0.4
Other direct personnel	0.0	0.0	0.2	0.1	0.1	0.1	0.1
Total direct personnel	0.1	1.1	1.1	0.5	0.5	0.5	0.5
Office of Environment, Safety, and Health							
Technical personnel	21.0	14.1	17.4	16.8	16.8	16.8	16.8
Other direct personnel	5.0	2.9	0.4	0.4	0.4	0.4	0.4
Total direct personnel	26.0	17.0	17.8	17.2	17.2	17.2	17.2

Table 7.4
(continued)

	1997	1998	1999	2000	2001	2002	2003
Office of Policyand International Affairs							
Technical personnel	2.0	1.5	2.0	0.9	0.9	0.9	0.9
Other direct personnel	0.3	0.6	0.0	0.0	0.0	0.0	0.0
Total direct personnel	2.3	2.1	2.0	0.9	0.9	0.9	0.9
Federal Energy Regulatory Commission							
Technical personnel	2.5	2.8	2.0	0.0	0.0	0.0	0.0
Other direct personnel	0.5	0.3	0.1	0.0	0.0	0.0	0.0
Total direct personnel	3.0	3.1	2.1	0.0	0.0	0.0	0.0
EM funding from LMES central financial plan and Bechtel Jacobs Co.							
Technical personnel	231.2	120.0	98.3	64.0	38.4	25.6	25.6
Other direct personnel	370.2	282.2	107.2	66.3	39.8	26.5	26.5
Total direct personnel	601.4	402.2	205.5	130.3	78.2	52.1	52.1
Subtotal DOE Programs							
Technical personnel	1048.1	1041.0	1234.4	1151.6	1126.1	1113.3	1113.3
Other direct personnel	664.7	606.5	583.4	552.1	525.6	512.3	512.3
Total direct personnel	1712.8	1647.5	1817.8	1703.7	1651.7	1625.6	1625.6
DOE Contractors and Operations Office							
Technical personnel	50.7	51.5	26.7	23.3	23.3	23.3	23.3
Other direct personnel	7.9	10.0	3.5	2.2	2.2	2.2	2.2
Total direct personnel	58.6	61.5	30.2	25.5	25.5	25.5	25.5
Cooperative R&D Agreements							
Technical personnel	6.2	5.6	4.7	4.4	4.4	4.4	4.4
Other direct personnel	0.8	0.8	0.0	0.0	0.0	0.0	0.0
Total direct personnel	7.0	6.4	4.7	4.4	4.4	4.4	4.4
Total DOE Programs							
Technical personnel	1105.0	1098.1	1265.8	1179.3	1153.8	1141.0	1141.0
Other direct personnel	673.4	617.3	586.9	554.3	527.8	514.5	514.5
Total direct personnel	1778.4	1715.4	1852.7	1733.6	1681.6	1655.5	1655.5
Work for others							
Nuclear Regulatory Commission							
Technical personnel	54.6	46.3	60.8	60.7	60.7	60.7	60.7
Other direct personnel	11.4	8.5	5.0	3.1	3.1	3.1	3.1
Total direct personnel	66.0	54.8	65.8	63.8	63.8	63.8	63.8
Department of Defense							
Technical personnel	78.1	88.0	105.9	109.6	109.6	109.6	109.6
Other direct personnel	7.9	9.8	10.1	6.3	6.3	6.3	6.3
Total direct personnel	86.0	97.8	116.0	115.9	115.9	115.9	115.9
National Aeronautics and Space Administration							
Technical personnel	0.0	12.1	15.7	16.3	16.3	16.3	16.3
Other direct personnel	0.0	1.7	3.8	3.8	3.8	3.8	3.8
Total direct personnel	0.0	13.8	19.5	20.1	20.1	20.1	20.1

Table 7.4
(continued)

	1997	1998	1999	2000	2001	2002	2003
Department of Health and Human Services							
Technical personnel	0.1	0.1	9.2	7.1	7.1	7.1	7.1
Other direct personnel	0.0	0.0	3.0	3.0	3.0	3.0	3.0
Total direct personnel	0.1	0.1	12.2	10.1	10.1	10.1	10.1
Environmental Protection Agency							
Technical personnel	21.0	21.0	21.8	17.4	17.4	17.4	17.4
Other direct personnel	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Total direct personnel	21.0	21.1	21.8	17.4	17.4	17.4	17.4
National Science Foundation							
Technical personnel	5.0	5.0	1.6	0.0	0.0	0.0	0.0
Other direct personnel	3.0	3.0	3.0	0.0	0.0	0.0	0.0
Total direct personnel	8.0	8.0	4.6	0.0	0.0	0.0	0.0
Federal Emergency Management Agency							
Technical personnel	2.3	2.3	4.5	4.1	4.1	4.1	4.1
Other direct personnel	1.0	1.0	3.5	3.3	3.3	3.3	3.3
Total direct personnel	3.3	3.3	8.0	7.4	7.4	7.4	7.4
Department of Transportation							
Technical personnel	21.3	22.8	42.0	39.5	39.5	39.5	39.5
Other direct personnel	11.1	11.1	8.1	7.2	7.2	7.2	7.2
Total direct personnel	32.4	33.9	50.1	46.7	46.7	46.7	46.7
Other Federal agencies							
Technical personnel	26.2	26.2	15.6	64.8	64.8	64.8	64.8
Other direct personnel	4.1	4.1	0.3	0.1	0.1	0.1	0.1
Total direct personnel	30.3	30.3	15.9	64.9	64.9	64.9	64.9
Electric Power Research Institute							
Technical personnel	6.3	5.2	3.5	2.9	2.9	2.9	2.9
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	6.3	5.2	3.5	2.9	2.9	2.9	2.9
Other nonfederal agencies							
Technical personnel	43.6	30.1	20.0	32.3	23.0	23.0	23.0
Other direct personnel	5.3	5.4	1.0	1.2	1.2	1.2	1.2
Total direct personnel	48.9	35.5	21.0	33.5	24.2	24.2	24.2
Total Work for Others							
Technical personnel	258.5	259.1	300.6	354.7	345.4	345.4	345.4
Other direct personnel	43.8	44.7	37.8	28.0	28.0	28.0	28.0
Total direct personnel	302.3	303.8	338.4	382.7	373.4	373.4	373.4
Total ORNL							
Technical personnel	1363.5	1749.3	1642.0	1598.1	1588.9	1588.9	1588.9
Other direct personnel	717.2	631.9	662.4	648.6	648.6	648.6	648.6
Total ORNL direct personnel	2080.7	2019.2	2191.1	2116.3	2055.0	2028.9	2028.9
Total ORNL indirect personnel	2339.3	2300.0	2100.0	2000.0	2000.0	2000.0	1950.0
Total ORNL personnel	4420.0	4319.2	4291.1	4116.3	4055.0	4028.9	4028.9

Supplemental Information

Table A.1 presents projected resources by program. The projections in Table A.1 are based on funding requested in the FY 1999 budget submission documents, with some adjustments for subsequent guidance. The projections include some funding for construction that supports the major laboratory initiatives proposed in Sect. 4 of the Institutional Plan.

Resource projections for future years are presented in terms of new budget authority (BA) funding in millions of dollars. New BA requests are calculated by adding estimates of fiscal year-end outstanding commitments (institutional, programmatic, and continued operation) to the total cost and then subtracting the prior-year uncosted budget. Personnel projections are given as the number of full-time equivalent (FTE) employees.

Tables A.2 and A.3 present information about ORNL's staff. Table A.4 presents estimates for subcontracting and procurement, reported as total obligated funds for each fiscal year, and Table A.5 presents estimates for small and disadvantaged business procurement.

Table A.6 provides details on the use of ORNL's designated user facilities during FY 1996. Table A.7 provides details on participants in ORNL's university and science education programs.

Table A.1
Resources by program by fiscal year
($ in millions)

	1997	1998	1999	2000	2001	2002	2003
Office of Energy Research							
Magnetic Fusion—AT							
Total operating	16.8	17.7	17.7	16.2	16.2	16.1	16.1
Capital equipment	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Total program	17.0	17.9	17.9	16.4	16.4	16.3	16.3
High Energy Physics—KA							
Total operating	0.3	0.7	0.3	0.3	0.3	0.3	0.3
Capital equipment	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total program	0.4	0.7	0.3	0.3	0.3	0.3	0.3
Nuclear Physics—KB							
Total operating	13.1	13.8	13.5	14.0	14.0	14.0	14.0
Capital equipment	1.8	2.0	2.0	2.0	2.0	2.0	2.0
Construction	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction	0.0	0.3	0.2	0.0	0.0	0.0	0.0
Total program	15.3	16.1	15.7	16.0	16.0	16.0	16.0
Basic Energy Sciences—KC							
Total operating	74.3	89.7	97.1	87.2	83.0	79.7	80.1
Capital equipment	4.3	5.8	5.0	5.1	5.5	6.1	4.0
General plant equipment (GPE)	4.3	4.3	4.7	0.0	0.0	0.0	0.0
Construction	5.6	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction	0.0	4.7	131.6	208.9	273.7	256.4	188.1
Total program	88.5	104.5	238.4	301.2	362.2	342.2	272.2
Compliance—KC03							
Total operating	0.0	3.6	1.9	5.3	1.3	0.0	0.0
Capital equipment	0.0	0.0	5.3	2.4	0.0	0.0	0.0
Proposed construction	0.0	0.1	2.4	1.3	0.0	0.0	0.0
Total program	0.0	3.7	9.6	9.0	1.3	0.0	0.0
Energy Research Analyses—KD							
Total operating	0.5	0.8	0.0	0.6	0.6	0.6	0.6
Multiprogram Energy Laboratory—Facility Support—KG							
Total operating	0.0	0.0	(0.4)	0.0	0.0	0.0	0.0
Capital equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction (MGPF)	(0.1)	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction	0.0	4.0	6.8	7.1	12.2	8.0	4.5
Total program	(0.1)	4.0	6.4	7.1	12.2	8.0	4.5
Computational and Technology Research—KJ							
Total operating	15.5	18.6	13.8	22.6	22.7	22.7	22.7
Capital equipment	1.0	0.5	0.8	2.8	3.0	2.6	0.0
Total program	16.5	19.1	14.6	25.4	25.7	25.3	22.7
Biological and Environmental Research—KP							
Total operating	22.6	24.9	23.1	24.0	24.0	24.0	24.0
Capital equipment	0.3	0.4	0.1	0.1	0.1	0.1	0.1
Proposed construction	0.0	0.0	0.0	8.0	4.0	0.0	0.0
Total program	22.9	25.3	23.2	32.1	28.1	24.1	24.1
Superconducting Super Collider—KS							
Total operating	(0.1)	0.0	0.0	0.0	0.0	0.0	0.0
University & Science Education—KT							
Total operating	0.2	0.3	0.3	0.3	0.3	0.3	0.3

Table A.1
(continued)

	1997	1998	1999	2000	2001	2002	2003
Total Office of Energy Research							
Operating expense	143.2	170.1	167.3	170.5	162.4	157.7	158.1
Capital equipment	7.7	8.9	13.4	12.6	10.8	11.0	4.3
General plant equipment (GPE)	4.3	4.3	4.7	0.0	0.0	0.0	0.0
Construction	5.9	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction	0.1	9.1	141.0	225.3	289.9	264.4	192.6
Total program	161.2	192.4	326.4	408.4	463.1	433.1	355.0
Office of Energy Efficiency and Renewable Energy							
Solar and Renewable Energy—EB							
Total operating	9.5	18.4	18.3	17.4	17.9	18.4	18.4
Capital equipment	0.3	0.0	0.1	0.1	0.1	0.1	0.1
Total program	9.8	18.4	18.4	17.5	18.0	18.5	18.5
Buildings Sector—EC							
Total operating	21.3	18.7	20.5	21.4	22.0	22.7	22.7
Industrial Sector—ED							
Total operating	12.5	15.1	15.8	18.2	18.7	19.3	19.3
Capital equipment	0.0	0.0	0.4	0.4	0.4	0.4	0.4
Total program	12.5	15.1	16.2	18.6	19.1	19.7	19.7
Transportation Sector—EE							
Total operating	21.7	32.2	33.5	35.7	36.8	37.9	37.9
Capital equipment	0.1	0.7	0.3	0.3	0.3	0.3	0.3
Total program	21.8	32.9	33.8	36.0	37.1	38.2	38.2
Policy and Management—EH							
Total operating	0.6	0.6	0.6	0.6	0.7	0.7	0.7
Federal Energy Management Program—EL							
Total operating	0.7	1.0	1.3	1.5	1.5	1.5	1.5
In-House Energy Management—WB							
Operating expense	0.0	0.0	(0.3)	0.0	0.0	0.0	0.0
Construction	0.0	0.8	0.0	0.0	0.0	0.0	0.0
Total program	0.0	0.8	(0.3)	0.0	0.0	0.0	0.0
Total Office of Energy Efficiency and Renewable Energy							
Operating expense	66.3	86.0	89.7	94.8	97.6	100.5	100.5
Capital equipment	0.4	0.7	0.8	0.8	0.8	0.8	0.8
Construction	0.0	0.8	0.0	0.0	0.0	0.0	0.0
Total program	66.7	87.5	90.5	95.6	98.4	101.3	101.3
Office of Nuclear Energy, Science and Technology							
Nuclear Energy R&D—AF							
Total operating	10.1	4.2	5.7	6.7	8.2	9.2	9.2
Capital equipment	0.1	0.0	0.1	0.1	0.1	0.1	0.1
Total program	10.2	4.2	5.8	6.8	8.3	9.3	9.3
Naval Reactors—AJ							
Total operating	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Uranium Enrichment—CD							
Total operating	(0.1)	0.0	(0.1)	0.0	0.0	0.0	0.0
Policy and Management—KK							
Total operating	(0.2)	0.0	0.0	0.0	0.0	0.0	0.0

Table A.1
(continued)

	1997	1998	1999	2000	2001	2002	2003
Isotope Production and Distribution Program—ST							
Total operating	13.5	10.7	12.2	12.5	12.5	12.5	12.5
Capital equipment	0.0	0.0	0.1	0.1	0.1	0.1	0.1
Total program	13.5	10.7	12.3	12.6	12.6	12.6	12.6
Total Office of Nuclear Energy, Science and Technology							
Operating expense	23.4	15.0	17.9	19.3	20.8	21.8	21.8
Capital equipment	0.1	0.0	0.2	0.2	0.2	0.2	0.2
Total program	23.5	15.0	18.1	19.5	21.0	22.0	22.0
Office of Fossil Energy							
Coal—AA							
Total operating	4.4	4.5	5.6	5.6	6.0	6.0	6.0
Gas—AB							
Total operating	1.9	1.9	2.6	1.7	1.8	1.8	1.8
Petroleum—AC							
Total operating	0.9	1.7	3.4	3.8	4.0	4.0	4.0
Fossil Energy Environmental Restoration—AW							
Total operating	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Strategic Petroleum Reserve—SA							
Total operating	0.1	0.1	0.1	0.2	0.2	0.2	0.2
Total Office of Fossil Energy							
Total operating	7.4	8.2	11.7	11.3	12.0	12.0	12.0
Energy Information Administration							
National Energy Information System—TA							
Total operating	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Energy Information Administration							
Total operating	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Office of Defense Programs							
Weapons Activities—DP							
Total operating	11.7	17.4	19.4	18.9	18.8	18.8	18.8
Capital equipment	0.0	0.0	0.5	1.5	0.5	0.5	0.0
Construction	1.6	1.5	2.0	2.0	2.0	0.0	0.0
Total program	13.3	18.9	21.9	22.4	21.3	19.3	18.8
Total Office of Defense Programs							
Total operating	11.7	17.4	19.4	18.9	18.8	18.8	18.8
Capital equipment	0.0	0.0	0.5	1.5	0.5	0.5	0.0
Proposed construction	1.6	1.5	2.0	2.0	2.0	0.0	0.0
Total program	13.3	18.9	21.9	22.4	21.3	19.3	18.8
Office of Nonproliferation and National Security							
Emergency Management—ND							
Total operating	0.1	0.0	0.1	0.1	0.1	0.1	0.1
Total Office of Nonproliferation and National Security							
Total operating	0.1	0.0	0.1	0.1	0.1	0.1	0.1
Office of Fissile Materials Disposition							
Fissile Materials Disposition—GA							
Total operating	10.6	13.7	10.5	13.0	12.0	14.0	12.0
Total Office of Fissile Material Disposition							
Total operating	10.6	13.7	10.5	13.0	12.0	14.0	12.0

Table A.1
(continued)

	1997	1998	1999	2000	2001	2002	2003
Office of Environmental Management							
Environmental Management—EM (in ORNL Financial Plan)[a]							
Total operating	0.0	33.1	26.0	17.9	14.9	14.9	14.9
Total Office of Environmental Management							
Total operating	0.0	33.1	26.0	17.9	14.9	14.9	14.9
Office of Civilian Radioactive Waste Management							
Nuclear Waste Fund—DB							
Total operating	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Office of Civilian Radioactive Waste Management							
Total operating	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Office of Environment, Safety and Health							
Environmental Research and Development—HA							
Total operating	(4.5)	0.0	0.0	0.0	0.0	0.0	0.0
Environment, Safety, and Health (Non-Defense)—HC							
Total operating	13.8	6.2	6.7	6.5	6.5	6.5	6.5
Environment, Safety, and Health (Defense)—HD							
Total operating	0.2	0.2	0.1	0.2	0.2	0.2	0.2
Nuclear Safety Policy—HP							
Total operating	(0.6)	0.0	0.0	0.0	0.0	0.0	0.0
Office of Nuclear Safety—NS							
Total operating	(0.6)	0.0	0.0	0.0	0.0	0.0	0.0
Total Office of Environment, Safety and Health							
Total operating	8.3	6.4	6.8	6.7	6.7	6.7	6.7
Office of Policy and International Affairs							
Emergency Planning—NC							
Total operating	0.2	0.0	0.0	0.1	0.1	0.1	0.1
Policy, Analysis, and Systems Studies—PE							
Total operating	0.5	0.5	0.4	0.4	0.4	0.4	0.4
Total Office of Policy and International Affairs							
Total operating	0.7	0.5	0.4	0.5	0.5	0.5	0.5
Federal Energy Regulatory Commission							
Federal Energy Regulatory Commission—VR							
Total operating	0.2	1.4	0.5	0.5	0. 6	0.1	0.1
Total Federal Energy Regulatory Commission							
Total operating	0.2	1.4	0.5	0.5	0. 6	0.1	0.1
Environmental Management (Central Financial Plan and Bechtel Jacobs Co.)							
Total operating	139.6	113.3	47.1	22.1	18.1	8.0	8.0
Capital equipment	0.0	1.6	0.4	0.4	0.4	0.5	0.5
Construction	0.1	1.4	0.0	0.0	0.0	0.0	0.0
Total program	139.7	116.3	47.5	22.5	18.5	8.5	8.5

Table A.1
(continued)

	1997	1998	1999	2000	2001	2002	2003
Subtotal—DOE Programs							
Operating expense	411.5	465.1	397.4	375.6	364.5	355.1	353.5
Capital equipment	8.2	11.2	15.3	15.5	12.7	13.0	5.8
General Plant Equipment (GPE)	4.3	4.3	4.7	0.0	0.0	0.0	0.0
Construction	7.6	3.7	2.0	2.0	2.0	0.0	0.0
Proposed construction	0.1	9.1	141.0	225.3	289.9	264.4	192.6
Total program	431.7	493.4	560.4	618.4	669.1	632.5	551.9
DOE Contractors and Operations Offices							
Operating expense	18.9	19.0	18.0	18.0	18.0	18.0	18.0
Capital equipment	0.2	0.1	0.0	0.0	0.0	0.0	0.0
Total program	19.1	19.1	18.0	18.0	18.0	18.0	18.0
Cooperative R&D Agreements							
Operating expense	2.2	1.8	0.7	1.1	1.2	1.3	1.4
Total DOE Programs							
Operating expense	432.6	477.7	426.1	393.7	383.2	374.4	373.4
Capital equipment	8.4	11.3	15.3	15.5	12.7	13.0	5.8
General Plant Equipment (GPE)	4.3	4.3	4.7	0.0	0.0	0.0	0.0
Construction	7.6	3.7	2.0	2.0	2.0	0.0	0.0
Proposed construction	—	9.1	141.0	225.3	289.9	264.4	192.6
Total	452.9	506.1	589.1	636.5	687.8	651.8	571.8
Work for others							
Nuclear Regulatory Commission							
Operating expense	13.3	10.8	10.8	13.0	13.0	13.0	13.0
Department of Defense							
Operating expense	25.2	26.0	27.0	28.0	30.0	32.0	32.0
Capital equipment	0.0	0.5	0.0	0.0	0.0	0.0	0.0
Total	25.2	26.5	27.0	28.0	30.0	32.0	32.0
National Aeronautics and Space Administration							
Operating expense	2.9	4.7	5.0	5.1	5.1	5.1	5.1
Department of Health and Human Services							
Operating expense	0.7	2.4	2.4	1.9	1.9	1.9	1.9
Environmental Protection Agency							
Operating expense	3.7	5.1	3.7	3.6	3.6	3.6	3.6
National Science Foundation							
Operating expense	1.2	0.2	0.1	0.0	0.0	0.0	0.0
Federal Emergency Management Agency							
Operating expense	0.7	3.1	3.0	1.5	1.5	1.5	1.5
Department of Transportation							
Operating expense	1.1	3.2	3.2	9.5	9.5	9.5	9.5
Other Federal agencies							
Total operating	19.1	12.6	12.0	13.6	16.2	15.3	16.9
Electric Power Research Institute							
Operating expense	1.6	1.1	1.0	0.9	0.9	0.9	0.9
Other nonfederal agencies							
Total operating	15.0	16.0	3.6	8.9	9.9	10.4	10.4

Table A.1
(continued)

	1997	1998	1999	2000	2001	2002	2003
Total Work for Others							
Total operating	84.5	85.2	71.8	86.1	91.7	93.3	94.9
Capital equipment	0.0	0.5	0.0	0.0	0.0	0.0	0.0
Total	81.5	85.7	71.8	86.1	91.7	93.3	94.9
Total Program Resources							
Operating expense	517.1	562.9	497.9	479.8	474.9	467.7	468.3
Capital equipment	8.4	11.8	15.3	15.5	12.7	13.0	5.8
General Plant Equipment (GPE)	4.3	4.3	4.7	0.0	0.0	0.0	0.0
Construction	7.6	3.7	2.0	2.0	2.0	0.0	0.0
Proposed construction	—	9.1	141.0	225.3	289.9	264.4	192.6
Total	**537.4**	**591.8**	**660.9**	**722.6**	**779.5**	**745.1**	**666.7**

[a]Prior to March 31, 1998, EM budgets were in the Lockheed Martin Energy Systems, Inc., Central Financial Plan.

Table A.2
Equal employment opportunity statistics for 1997

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]	383 (88.7)	49 (11.3)	28 (6.5)	3 (0.7)	355 (82.2)	46 (10.6)	24 (5.6)	3 (0.7)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	4 (0.9)	0 (0.0)
Professional staff[e]														
Scientists/ engineers	1379 (85.2)	239 (14.8)	148 (9.1)	34 (2.1)	1231 (76.1)	205 (12.7)	34 (2.1)	15 (0.9)	26 (1.6)	3 (0.2)	1 (0.1)	1 (0.1)	87 (5.4)	15 (0.9)
Administrative	74 (36.1)	131 (63.9)	5 (2.4)	11 (5.4)	69 (33.7)	120 (58.5)	5 (2.4)	7 (3.4)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	4 (2.0)
Other professional	192 (73.0)	71 (31.0)	13 (4.9)	7 (2.7)	179 (68.1)	64 (24.3)	11 (4.2)	4 (1.5)	1 (0.4)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.4)	3 (1.1)
Technicians	281 (68.0)	132 (32.0)	22 (5.3)	12 (2.9)	259 (62.7)	120 (29.1)	15 (3.6)	9 (2.2)	5 (1.2)	0 (0.0)	1 (0.2)	0 (0.0)	1 (0.2)	3 (0.7)
Clerical	12 (1.9)	617 (98.1)	3 (0.5)	73 (11.6)	9 (1.4)	544 (86.5)	3 (0.5)	62 (9.9)	0 (0.0)	5 (1.2)	0 (0.0)	1 (0.2)	0 (0.0)	4 (0.6)
Crafts/ laborers	722 (91.9)	64 (8.1)	75 (9.5)	14 (1.8)	647 (82.3)	50 (6.4)	70 (8.9)	13 (1.7)	1 (0.1)	0 (0.0)	1 (0.1)	1 (0.1)	3 (0.4)	0 (0.0)
Service workers	43 (59.7)	29 (40.3)	10 (13.9)	12 (16.7)	33 (45.8)	17 (23.6)	10 (13.9)	9 (12.5)	0 (0.0)	0 (0.0)	0 (0.0)	1 (1.4)	0 (0.0)	2 (2.8)
Total	3086 (69.9)	1332 (30.1)	304 (6.9)	166 (3.8)	2782 (63.0)	1166 (26.4)	172 (3.9)	122 (2.8)	33 (0.7)	9 (0.2)	3 (0.1)	4 (0.1)	96 (2.2)	31 (0.7)

[a]Percentage of total number of employees in occupational category.
[b]M = male.
[c]F = female.
[d]As defined on Standard Form 100 (EEO-1), as required by 41 CFR 60-1.7(a).
[e]Management included in "Officials and managers" category.

Table A.3
ORNL staff composition (as of December 31, 1997)[a]

	Ph.D.	M.S.	B.S./B.A.	Other	Total
		Professional staff			
Scientists	515	305	215	111	1146
Engineers	245	233	168	34	680
Management/administrative	96	151	198	256	701
		Support staff			
Technicians	0	6	89	316	411
All other	0	5	95	1400	1500
Total ORNL staff	856	700	765	2117	4438

[a]Includes full-time and part-time employees.

Table A.4
Estimated subcontracting and procurement by fiscal year
($ in millions—obligated)

	1997[a]	1998[a]	1999	2000
Universities	29.6	20.7	31.4	32.3
All others	148.2	152.4	157.2	161.9
Transfers to other DOE facilities	2.1	1.2	2.2	2.3
Total external subcontracts and procurements	179.9	174.3	190.8	196.5

[a]Actual.

Table A.5
Estimated small and disadvantaged business procurement by fiscal year

	1997	1998
Total small and disadvantaged business procurement, in millions of dollars	84.7	89.3
Small and disadvantaged business procurement as a percentage of total procurement	47%	51%

Table A.6

Experimenters at ORNL's designated user facilities in FY 1997

	U.S. government laboratory[a]			University			Industry			International			Total		
	Exp.[b]	Org.[b]	% of use	Exp.	Org.	% of use	Exp.	Org.	% of use	Exp.	Org.	% of use	Exp.	Org.	User days
Bioprocessing R&D Center	5	1	46	4	2	48	4	2	6	0	0	0	13	5	217
Buildings Technology Center	5	2	4	31	6	72	91	9	23	5	2	1	132	19	1,550
Californium User Facility for Neutron Sciences	0	0	0	4	2	100	0	0	0	0	0	0	4	2	48
Computational Center for Industrial Innovation	12	3	3	2	1	19	2	2	9	18	8	69	34	14	216
EN Tandem Van de Graaff	2	1	100	0	0	0	0	0	0	0	0	0	2	1	54
High Temperature Materials Lab.	6	1	68	82	29	14	68	31	18	0	0	0	156	61	20,105
Holifield Radioactive Ion Beam Facility	23	3	59	15	6	31	0	0	0	8	5	15	46	14	419
Materials and Chemistry Lab.	0	0	0	2	2	43	3	2	57	0	0	0	5	4	92
Metals Processing Lab.	12	1	79	4	3	2	39	24	19	0	0	0	55	28	584
Metrology R&D Lab.	18	4	90	2	1	3	17	13	7	0	0	0	37	18	1,083
Neutron Scattering Research Facilities at HFIR	43	8	91	66	28	4	6	6	1	33	24	4	148	66	8,543
Oak Ridge Centers for Manufacturing Technology	0	0	0	38	3	85	11	5	15	0	0	0	49	8	236
Oak Ridge Electron Linear Accelerator[c]	8	1	79	2	2	21	0	0	0	0	0	0	10	3	1,040
Oak Ridge National Environmental Research Park[d]	54	6	68	77	33	31	0	0	0	5	5	1	136	44	5,346
Shared Research Equipment Program	41	2	84	34	23	12	5	5	1	3	3	3	83	33	3,581
Surface Modification and Characterization Research Center	28	4	66	30	14	31	2	2	1	2	2	2	62	22	3,248
Total	257	37	52	393	155	32	248	101	10	74	49	6	972	342	46,362

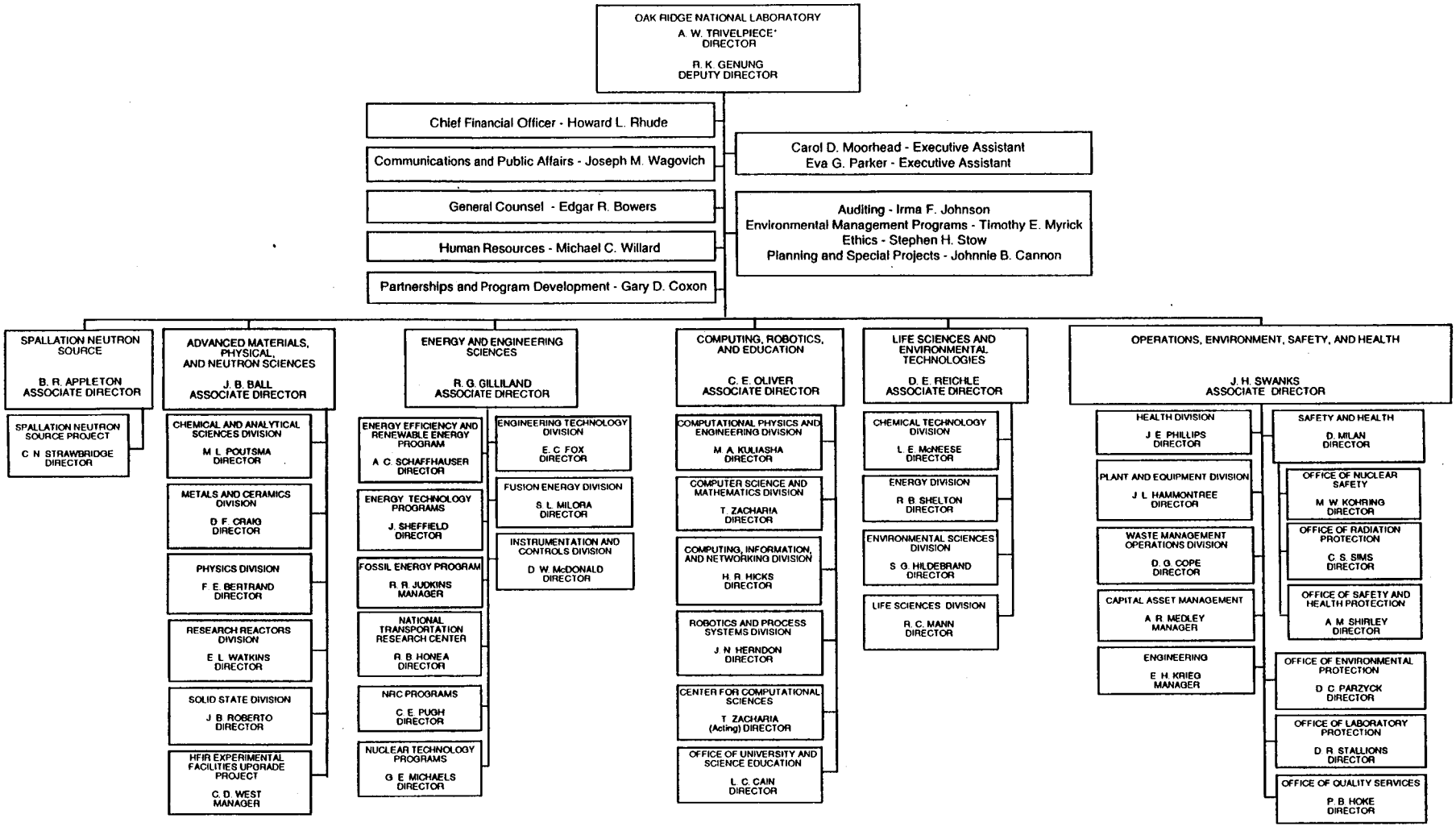
[a]Includes 161 ORNL users (16% of use).
[b]Exp. = number of experimenters; Org. = number of organizations.
[c]Staff members at this facility use Beam Line A 100% during operation.
[d]Numbers do not include more than 11,000 individuals who participated in the Ecological and Physical Sciences Study Center and the High School Honors Program for a total of 13,668 user hours in FY 1997.

Table A.7
University and science education

	FY 1997		
	Total	Minorities	Women
Precollege student programs			
Adventures in Supercomputing	436	111	213
ARC Honors Academy	38	3	16
Project SEED/Hispanic SEED	6	1	5
Saturday Academy of Computing and Mathematics	33	2	4
Special Honors Study	2	0	1
Total	515	117	239
Precollege teacher programs			
Adventures in Supercomputing	70	5	39
ARC Teacher Leadership Institute	18	9	7
DOE Teacher Research Associates	7	0	3
Saturday Academy of Computing and Mathematics	26	0	26
Teacher In-Service Training	48	0	40
Total	169	14	115
Undergraduate programs			
Alliance for Minority Participation	4	4	4
DOE Science and Engineering Research Semester	35	3	16
Great Lakes Colleges Association/ Associated Colleges of the Midwest Science Semester	18	5	7
HBCU			
Nuclear Energy	23	23	12
Nuclear Regulatory	8	8	4
NAACP Scholar	1	1	1
Professional Internship Program	26	3	11
Science and Engineering Research Semester, Summer Program	6	0	2
Student Research Participation Program	64	16	29
Summer Technical Internship	16	7	6
Technology Internship Program	10	0	6
University of Puerto Rico	6	6	6
Total	217	76	104
Graduate programs			
Advanced Industrial Concepts Materials Fellowship Program	3	2	2
DOE Fellowship Practicums	8	1	3
Graduate Student Research Participation Program	15	1	4
High Temperature Materials Laboratory Fellowships	11	0	4
Laboratory Graduate Research	7	0	2
Law Internship Program	2	0	2
NRC HBCU Graduate Student Research Program	2	2	0
OBER HBCU Graduate Student Research Program	1	1	0
Professional Internship Programs	49	11	16
Research Travel Contracts	42	3	14
Science and Technology Alliance	2	2	0
Total	142	23	47

Table A.7
(continued)

	FY 1997		
	Total	Minorities	Women
Postgraduate programs			
DOE Postdoctoral Programs			
Distinguished Postdoctoral	10	2	1
Fusion Energy	9	2	0
Hollaender	23	6	7
Human Genome	6	1	1
Postgraduate Research Training Program	84	23	20
Wigner Postdoctoral Fellows	7	1	0
Total	139	35	29
Faculty programs			
Faculty Research Participation	28	13	0
Great Lakes Colleges Association/ Associated Colleges of the Midwest	3	0	1
HBCU Faculty Research	13	11	0
High Temperature Materials Laboratory Fellowships	4	0	1
Research Travel Contract Visits	130	31	17
Total	178	55	19



*DR. TRIVELPIECE REPORTS TO THE PRESIDENT OF LOCKHEED MARTIN ENERGY AND ENVIRONMENT SECTOR

JANUARY 1999