ORNL/PPA-97/2

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OAK RIDGE
NATIONAL
LABORATORY

LOCKHEED MARTIN

Oak Ridge National Laboratory

Institutional Plan

FY 1998–FY 2002

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

ORNL/PPA-97/2

Oak Ridge National Laboratory Institutional Plan

FY 1998–FY 2002

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

1. Laboratory Director's Statement

In January 1996, the responsibility for managing and operating the Oak Ridge National Laboratory (ORNL) was transferred to Lockheed Martin Energy Research Corporation. One of the purposes of this transition was to give the Laboratory the opportunity to establish a management structure that is appropriate to ORNL's role as a Department of Energy (DOE) national laboratory.

I am pleased to report that ORNL is taking good advantage of this opportunity. Improvements in its operations are matched by advances in science and technology that address the challenges facing DOE, the nation, and the world.

A Laboratory-wide reengineering effort is improving ORNL's competitiveness both by reducing costs and by enhancing the Laboratory's ability to attract and retain outstanding scientific, engineering, and support talent. Teams have been chartered and charged with examining seven key areas: business management, human resources, research support services, implementation of Work Smart standards, science and technology partnerships, engineering design and construction, and waste management. The recommendations of these teams are leading to significant changes in ORNL's operating environment; these include the implementation of a new business software system, modifications in the Laboratory's compensation and performance management programs, the development of labor-management teams to improve productivity in research support services, and the integration of safety management into all facets of work planning and execution.

In parallel with the improvements resulting from the reengineering effort, ORNL is seeking new opportunities through initiatives in neutron science, functional genomics, and distributed computing.

- The conceptual design for the proposed Spallation Neutron Source, developed in a collaboration that brings together the broad expertise of five national laboratories, has been endorsed by a review committee. The project is now included as a construction line item in the President's FY 1999 budget. Upgrades to ORNL's High Flux Isotope Reactor will also help to enhance the Laboratory's capabilities in neutron science.
- ORNL's work in functional genomics looks ahead to the next phase of human genome research—the determination of gene function—and applies the Laboratory's 50-year heritage in mouse genetics and its vast mutagenesis resources and capabilities to this important task. The Joint Institute for Biological Sciences recently created by ORNL and the University of Tennessee multiplies the resources available to both organizations and formalizes their long-standing collaborative relationship in this area.
- ORNL and Sandia National Laboratories are pursuing the development of the computing environment needed to address major scientific challenges through a collaboration on the networking of widely distributed, heterogeneous high-performance computers.

These initiatives build on ORNL's strengths and current programs for exploring the frontiers of science and technology. They also demonstrate the Laboratory's commitment to partnerships as a means of delivering greater opportunities and benefits.

ORNL's partners in science and technology include other DOE laboratories and facilities, universities, industry, and other research institutions. Through these partnerships, the Laboratory creates knowledge, develops and transfers technology, and contributes to education. For example, of the nine R&D 100 awards presented this year to ORNL, two were joint entries with the Oak Ridge Y-12 Plant and one involved a small company that has licensed an ORNL-developed technology.

ORNL researchers are also the recipients of two Presidential Early Career Awards, recognizing demonstrated excellence and promise of future success in scientific or engineering research; a Presidential Green Chemistry Challenge Award, presented to a team that included three ORNL staff members, for applying fundamental or innovative chemical methods with broad industry applications to pollution problems; and the Christopher Columbus Fellowship Foundation Award to encourage the continuation of innovative work. Such recognition of the excellence of ORNL's science and technology is gratifying.

Of equal importance to the Laboratory, however, is recognition of the value of its work by those beyond the research community. Thus, ORNL is dedicated to improving the public understanding of science and technology at national, state, and local levels and to building good relationships with its neighbors. Outreach programs such as Community Day, public tours, and a toll-free number for media inquiries help to bring ORNL and its programs into the public view.

One encouraging response has been widespread regional support for the Spallation Neutron Source. This project is a key element in ORNL's plans, described in this document, to meet challenging scientific and technical goals and to become a more efficient, cost-effective institution that offers the best possible support for DOE missions.

2 • Laboratory Missions

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 • Mission Roles

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
  - Environmental and social sciences
  - Fusion science and technology
  - Genetics, genomics, and biotechnology
  - Materials science and engineering
  - Neutron science
  - Nuclear physics and astrophysics with radioactive ion beams
- **Energy Resources**
  - Biomass: renewable energy feedstock and conversion technologies
  - Energy-efficient technologies for buildings, industrial, transportation, and utility end-use
  - Fossil fuel: applied materials and turbines
  - Nuclear technology and safety
- **Environmental Quality**
  - Environmental restoration and waste management
  - 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

2.2 • Mission Execution

In executing its mission assignments, ORNL is governed by the following 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 Department of Energy 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.

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. 2.2.2), and talented staff.

ORNL focuses its capabilities through several areas of R&D emphasis, described in detail in Sect. 2.2.1:

- 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. 2.2.3.

Four institutional strengths cross-cut the technical competencies and the technical foundations and are important characteristics of the Laboratory as a whole: development and operation of national research facilities, R&D integration and partnerships, technology transfer, and science education.

2.2.1 • Areas of R&D Emphasis

2.2.1.1 • 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.

2.2.1.2 • 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 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.

2.2.1.3 • 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.

2.2.1.4 • 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 efforts 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.

2.2.1.5 • 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 science; 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.

2.2.1.6 • 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.

2.2.2 • 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 16 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 western 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.
- **Laboratory for Comparative and Functional Genomics (LCFG).** ORNL's LCFG is home to 92,000 mice, supporting a genetics and functional genomics program of unique scope and size. Approximately 1,000 lines of mutant mice have been developed and are maintained as breeding stocks. These lines represent 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.** ORNL manages a total of 21,500 acres for environmental research and education, including 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 is one of two high-performance computing research centers established as part of DOE's contribution to the national High Performance Computing and Communications Program. Home to an Intel Paragon XP/S 150 supercomputer, the CCS is one of the foremost computing centers in the world.
- **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 other DOE national laboratories and installations, academic institutions, and industrial facilities.
- **Surface Modification and Characterization Research Center (SMACRC).** The SMACRC is used for fundamental materials research on topics such as crystal growth, material stability, and radiation effects. Researchers apply ion implantation doping, ion beam mixing, ion beam deposition, ion beam annealing, and Rutherford scattering to modify and characterize near-surface regions of materials.

2.2.3 • 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.

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, as described in Sect. 6.1.

2.2.3.1 • Science and Technology

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

Magnetic Fusion

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.

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.

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 advan-

tage 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.

ORNL has unique resources for the construction and operation of a National Isotope Separator On-Line (ISOL) Facility, for which the HRIBF can be considered a prototype.

Initiative: National ISOL Facility

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

First-generation ISOL facilities are being built in Europe, Japan, and North America. The Holifield Radioactive Ion Beam Facility (HRIBF) at ORNL, which started user operations in March 1997, is the first such facility that can address 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) necessary to take full advantage of the scientific opportunities afforded by this new interdisciplinary research tool. Topics to be studied in an advanced ISOL facility 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 a variety 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 studies associated with deep implantation of radioactive nuclear species.

With the expertise derived from building and operating the HRIBF, ORNL is in a leading position to compete for this facility, which has an estimated cost of $100 million to $200 million. Furthermore, the scientific program of such a facility is in line with the traditional interests of the ORNL Physics Division staff and the users of the HRIBF.

The configuration of the National ISOL Facility is not yet fixed; a layout that takes advantage of resources at ORNL is shown in Fig. 2.1. Very intense light-ion beams from a $K \approx 200$ cyclotron or a linear accelerator (linac) would be used to produce radioactive atoms from fission, fusion-evaporation, and spallation reactions in a high-temperature thick target on a high-voltage injection platform. After diffusion from the target, the radioactive atoms would be ionized, mass selected, and, if necessary, charge exchanged before acceleration to ground potential. A high-resolution isobar separator would select a single isobar for acceleration in ORNL's 25-MV tandem accelerator. After acceleration, the radioactive ions would be boosted to their final energy by a superconducting linac. The availability of the 25-MV tandem accelerator and the location of the cyclotron and the target-ion source platform in heavily shielded areas make this configuration cost-effective.

The National ISOL Facility could also be constructed to use intense high-energy proton beams from the proposed Spallation Neutron Source (SNS; see Sect. 4.1). The SNS performance requirements call for a linac that would initially produce 1 mA of 1-GeV protons, upgradable to "significantly higher power." A small

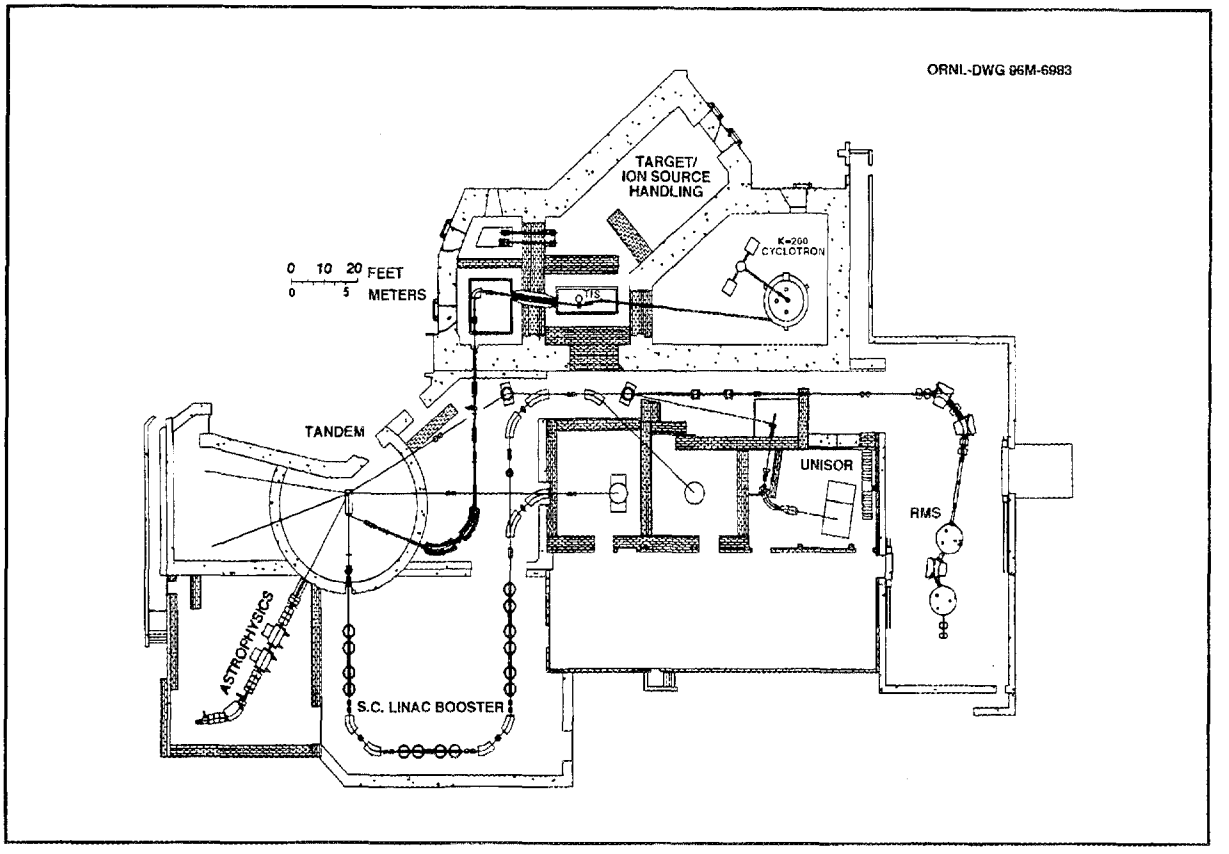


Figure 2.1
Possible layout for the National ISOL Facility in Building 6000 at ORNL.

fraction of the 1-GeV proton beam would be the ultimate production beam for the National ISOL Facility. High-energy protons for the production of radioactive ions could be taken at the neutral hydrogen beam dump (where the H^- beam is stripped to H^+ for injection into the accumulator ring) or obtained by extracting an occasional beam pulse from the 30- to 60-Hz beam structure of the accumulator ring. The higher-energy proton beam would provide both higher intensity and a greater variety of radioactive ions for acceleration than would the layout in Fig. 2.1.

ORNL staff are working to finalize the concept of the National ISOL Facility and plan to submit a proposal for its construction to DOE in the autumn of 1998. 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 that have half-lives greater than about a second and are sufficiently volatile to defuse from a hot target. Intense beams of these isotopes are not available from first-generation ISOL facilities such as the HRIBF. The advanced facility will also provide a larger variety of proton-rich RIBs than the HRIBF can supply. Both proton- and neutron-rich RIBs will be accelerated from tens of kiloelectron volts for materials science studies and radioactive target preparation to above the Coulomb barrier, thereby allowing nuclei to fuse for nuclear structure studies.

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.

Basic Energy Sciences

The DOE-ER 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 fundamental materials R&D including neutron scattering; synthesis and characterization of new materials; high-temperature materials; ceramic processing; superconductivity; surfaces and thin films; synchrotron research; ion beam, laser, and plasma processing; and theoretical studies for advanced energy-related materials. This program also supports four user programs: 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 (ORISE): the ORNL-ORISE Synchrotron Organization for Advanced Research and the Shared Research Equipment (SHaRE) Program. 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-ER.

ORNL is a leader in the development of advanced materials, processes, and characterization technologies. Interdisciplinary research in condensed matter and materials physics advances the understanding of materials and materials-related phenomena that underpin energy technologies. Work in materials chemistry focuses physicochemical methods on the synthesis and characterization of advanced inorganic materials and organic polymer systems. Key endeavors with an impact on materials R&D include ORNL participation in the Partnership for a New Generation of Vehicles, environmental technology development, the crosscutting proposal for a National Center for Crystal Growth described in Sect. 6.1.1.1, and the initiative for an Advanced Materials Characterization Laboratory.

Initiative: Advanced Materials Characterization Laboratory

ORNL has one of the nation's strongest and broadest materials sciences programs. Its expertise ranges from superconductors to intermetallic structural alloys, from multilayer structures grown one layer of atoms at a time to modern casting technologies for aluminum alloys, and from basic science to development of materials with industry. ORNL's resources are the focus of collaborative research with universities and industries across the United States because of user facilities such as the High Flux Isotope Reactor (HFIR), the Shared Research Equipment Program, the Surface Modification and Characterization Research Center, and the High Temperature Materials Laboratory.

Characterization of materials is an essential component of this program. In this area, ORNL is a leader in the development of a wide range of techniques and instrumentation for analysis of materials at the atomic level. Today it is possible to correlate many of the properties of a material with the organization of the various kinds of atoms that make up the material. Major probes for characterizing materials include neutrons, X rays (or light), and electrons (and related techniques).

As the complexity of materials and the requirements on their performance have increased, demands for detailed information about the structure of materials have soared. To provide this information, ORNL must maintain cutting-edge characterization tools in each of these areas.

For neutron science, this need will be met by the Spallation Neutron Source (SNS) and the upgrades to the HFIR and associated neutron scattering facilities. X-ray characterization needs are being addressed by ORNL beam lines at

Argonne National Laboratory's Advanced Photon Source. However, investments to meet future needs for electron characterization and related techniques are lagging those in the other areas.

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

The Advanced Materials Characterization Laboratory (AMCL) is proposed to meet these needs. A new structure with 3,000 m^2 (32,000 ft^2) of space 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. The AMCL will foster the 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.

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 1999, with construction to be completed in FY 2002.

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 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 300 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 experimental and theoretical atomic physics and research performed to improve the fundamental understanding of methods for separating mixtures, issues underlying analytical techniques, the physical and chemical properties of actinides, advanced battery technology, and systems related to chemical conversions that underpin new or existing concepts of energy production and storage.

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. 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-ER 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, one of two DOE high-performance computing research centers, and the conduct of basic research through the Applied Mathematical Sciences (AMS) subprogram. The distributed computing initiative described in Sect. 4.3 will combine CCS and Sandia National Laboratories resources and expertise to

support DOE's missions in national security and science. 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. 6.1.4.2, provides a means for ORNL to team with universities, other laboratories, and industry partners in building capabilities for telepresence and collaborative environments.

OCTR also provides support for innovative, high-risk research that does not fall under the auspices of other DOE programs. The Advanced Energy Projects Program addresses such areas as novel biotechnology, advanced materials, chemical, and environmental research. The Energy Research Laboratory Technology Research Program supports projects that build on a mix of basic and applied research to promote substantial changes in technology areas of strategic importance to DOE and American industry. Mechanisms include technology research and maturation projects and cost-shared collaborations such as cooperative R&D agreements (CRADAs), personnel exchanges, and technical assistance projects.

Biological and Environmental Research

The ORNL Biological and Environmental Research (BER) Program, under the sponsorship of the DOE-ER 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. An initiative in large-scale environmental process research will focus ORNL capabilities, some developed in support of other missions, on the task of overcoming major scientific uncertainties in the understanding of large-scale environmental issues.

Initiative: Large-Scale Environmental Process Research

ORNL has developed leading-edge capabilities, distributed across the Laboratory, for measurement, modeling, and monitoring of the environment. ORNL proposes to combine these capabilities with its unique resources for long-term environmental research to create a Center

for Large-Scale Environmental Process Research. The Laboratory will leverage and enhance current assets in large-scale ecosystem manipulation, integrated data management, ecological modeling, measurement science and sensor development, and computational science to define and create new approaches to ecosystem process research.

A well-focused R&D program is needed to overcome major scientific uncertainties in the understanding of large-scale (regional, national, global) environmental issues. Challenges in this area may include adapting to climate change, sustainably managing resources, or understanding the impacts of changes in air, water, or soil quality. Understanding the processes that control ecosystem response is a key to the ability to extrapolate from measurable phenomena to those best approached by modeling. An enhanced program of research is needed to build an understanding of these processes.

Environmental processes are active and variable at temporal scales from nanoseconds to millennia and at spatial scales from single molecules to the globe, making predictability across space and time highly uncertain. Improving the understanding of heterogeneous systems and the ability to predict across scales in these systems is important in quantifying how the environment works and in finding sustainable ways to use goods and services.

One major challenge in environmental science today is predicting an outcome that results from multiple interacting factors (e.g., tropospheric ozone, global warming, changing precipitation patterns, or high nitrogen or trace metal loading). Environmental processes are typically studied in isolation. Rarely have interactions between these processes, or between processes and the multiple stressors that influence them, been studied or quantitatively characterized. The loss of nonlinearities introduced by these interactions contributes significantly to uncertainty in the understanding of future outcomes.

ORNL has pioneered advances in methodology and approaches to the study of events that define physical, chemical, or biological change in the environment. Process-level studies reveal how natural systems function and are critical to understanding the dynamics and response of ecosystems in a changing environment. Interpretations and assessments of environmental impacts from human activities are based on an understanding of environmental processes.

ORNL has played a leading role in establishing approaches to studying natural ecosystems on a large scale and in documenting that, for example, mature forests do not respond in the same manner as collections of seedlings or small trees. Verification and validation of modeling approaches to extrapolate from such small-scale experiments to ecosystem, landscape, or regional scales require the resources for in situ experimental manipulation of the larger scale environment.

The Center for Large-Scale Environmental Process Research will build on the well-developed DOE and ORNL investments in scientific infrastructure at the Oak Ridge National Environmental Research Park. This concentration of resources is unique among ecological research centers in the United States. In addition to major large-scale ecosystem manipulation experiments and the Walker Branch Watershed, the site 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 35,516-acre Oak Ridge Reservation is a unique and irreplaceable resource for addressing national science and technology missions. Continued leadership by ORNL in land use planning for the reservation will ensure that this resource is maintained to support the science initiatives of the Center for Large-Scale Environmental Process Research and key missions of ORNL and DOE.

The center, through its unique component facilities, 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. New developments in measurement science and technology will use large-scale ecosystem manipulations as a test bed for development of the next generation of sensors and environmental monitoring instrumentation and for 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."

DOE-ER's Office of Biological and Environmental Research is the core sponsor of this activity; complementary funding is being sought from other DOE programs and federal agency sponsors. Table 2.1 provides a summary of the projected funding.

Table 2.1
Funding projections for Large-Scale Environmental Process Research Center by fiscal year

	1998	1999	2000	2001	2002
Operating	2.0	3.0	5.0	7.0	8.0
Capital	0.4	0.4	0.2	0.2	0.2
Construction	1.0	0.5	1.5	2.0	1.0

An integrated R&D initiative in global science and technology (see Sect. 6.1.3.2) also brings 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 Laboratory for Comparative and Functional Genomics, the Oak Ridge National Environmental Research Park, and the Bioprocessing R&D Center. The ORNL Center for Biotechnology (see Sect. 6.1.3.1) 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. 6.1.3.2) integrates the Laboratory's science and technology to understand environmental processes and support sustainable development.

2.2.3.2 • 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 in 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. 2.2.3.6 and 6.1.2.2.

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" hat convert sugars (instead of today's petroleum feedstocks) to industrial chemicals. Other research in 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. Integrated R&D activities in this area are described in Sect. 6.1.2.1.

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 Turbines System 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.

DOE has proposed a nuclear energy R&D program beginning in FY 1999. ORNL expects to contribute to four mission areas within this program: (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. 6.1.3.3 and 6.1.3.4.

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.

2.2.3.3 • Environmental Quality

Environmental Management

DOE's Office of Environmental Management (DOE-EM) provides funding to ORNL for (1) correcting existing problems, preventing future problems, managing waste, and minimizing waste generation at ORNL, as described in Sect. 5.4, and (2) R&D and technical support for addressing environmental management problems, principally at DOE sites, with increasing emphasis on technology transfer. Some of this work has been funded through Lockheed Martin Energy Systems, Inc. (LMES), which has managed the Environmental Management and Enrichment Facilities (EMEF) Program in Oak Ridge. In 1998, the management of this program will be transferred to a new management and integration (M&I) contractor. It is expected that ORNL will continue to support the EMEF Program through agreements with the M&I contractor.

ORNL supports DOE-EM remedial action projects by characterizing and verifying the radiological status of sites involved. Advancement of 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.

The Groundwater Program Office at ORNL provides technical coordination for all groundwater activities at DOE sites in Oak Ridge and at DOE's gaseous diffusion plants. The Oak Ridge Hydrology Support Program offers technical expertise in hydrology and geology to support site groundwater programs staff in handling water issues related to environmental restoration and compliance.

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 scientists are also 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. 6.1.3.4); and robotics technologies (see Sects. 6.1.2.3 and 6.1.4.1). 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 conducted under DOE's Environmental Management Science Program, a collaborative initiative administered by DOE-EM and DOE-ER.

Environment, Safety, and Health

ORNL's work for the DOE Office of Environment, Safety, and Health (DOE-EH) is described in detail in *ORNL Research and Technical Support Programs Funded by the Assistant Secretary for Environment, Safety and Health: FY 1996,* ORNL/M-5809, Lockheed Martin Energy Research Corp., 1996. A program manager coordinates all R&D and technical support activities funded by DOE-EH. Activities include technical standards, nuclear safety policy and standards, criticality safety analyses, performance indicators, occurrence reporting and processing system, environmental policy and assistance, occupational safety and health, deactivation and decommissioning field support, epidemiology and health surveillance, and business performance systems.

2.2.3.4 • National Security

Office of 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 cosponsored by DOE-ER. 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 6.1.3.3 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 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.

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. 6.1.3.3.

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.

2.2.3.5 • 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.

2.2.3.6 • 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.

Major research areas for AEOD involve the review, analysis, and evaluation of operating reactor safety performance data for both domestic and foreign reactors and assessments of procedures and software tools used by response personnel in the event of a nuclear accident. Two major activities are the Sequence Coding Search System (SCSS) database of Licensee Event Report data, which involves a system of reducing the descriptive text

contained in the reports to coded sequences, and the Accident Sequence Precursor (ASP) program, which evaluates commercial nuclear plant operational data from a risk standpoint.

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. 6.1.2.3).

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 technical support to the National Acid Precipitation Assessment Program II; 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. 6.1.2.2) 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.

American Petroleum Institute • The American Petroleum Institute supports research at ORNL to evaluate the pharmacokinetics and pharmacodynamics of benzene in humans. The aim is to improve estimates of the risk of developing leukemia following exposure to low doses of benzene.

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.

2.2.3.7 • 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-ER 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. *ORNL Laboratory Directed Research and Development Program: Annual Report to the Department of Energy Summarizing Fiscal Year 1996,* ORNL/PPA-97/1, 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 the following strategic goals and objectives to move the Laboratory toward its vision.

- **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

- **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 to design 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

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 science, 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. ORELA now concentrates on nuclear astrophysics and basic neutron properties (e.g., neutron electric polarizability) research, but it is also available for other applications, such as target experiments for the proposed Spallation Neutron Source (SNS), and as a positron beam facility.

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 separate stable isotopes for use by outside researchers 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 mission. This initiative incorporates the following activities:

- Upgrades and refurbishment of the HFIR, which would make the HFIR the most powerful research reactor in the world and greatly enhance the Laboratory's already unique neutron science capabilities and programs.
- Design of the SNS, a next-generation spallation neutron source facility being designed for DOE in collaboration with four other DOE national laboratories.
- Establishment of a Joint Institute for Neutron Sciences, in cooperation with the University of Tennessee (UT), to accommodate the 1000 to 2000 users expected each year from universities, U.S. industry, and other laboratories.

4.1.1 • High Flux Isotope Reactor Upgrade

The HFIR is one of the world's most important and powerful research reactor facilities. At its current operating power of 85 MW, it has a peak thermal neutron flux of 2.6×10^{15} neutrons/cm^2•s, highest in the western world. This give the HFIR unique capabilities for producing important radioisotopes and providing facilities for materials irradiation, NAA, and neutron beam scattering studies.

The proposed SNS (see Sect. 4.1.2) 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 Office of Basic Energy Sciences in DOE's Office of Energy Research (DOE-ER) 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 30 years or more and will provide a unique resource for neutron-based science.

4.1.2 • Spallation Neutron Source

Neutrons used in scientific research are produced in two ways. The more familiar way, fission, occurs in nuclear reactors. Within a nuclear reactor, enough uranium is brought together to sustain a controlled nuclear chain reaction that produces excess neutrons, which can be used for research. The second method, spallation, produces neutrons when a target made up of atoms having massive nuclei is bombarded by energetic protons from a high-energy accelerator. When a proton smashes into the target nuclei, neutrons are ejected as a result of nuclear reactions initiated by the incident proton. Each high-energy proton in these spallation reactions typically releases 20 to 30 neutrons. These neutrons have energy distributions similar to those from a fission reaction, and they can be moderated and guided into an experimental area for research.

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

DOE has worked closely with the science community since the early 1970s in planning for the future needs for neutron sources. In 1996, DOE's Basic Energy Sciences

Advisory Committee (BESAC) strongly reaffirmed the need for a next-generation, pulsed spallation neutron source to meet the future needs of the scientific community. This assessment followed a 1993 BESAC study, *Neutron Sources for America's Future,* which provided a comprehensive assessment of the needs and options for new neutron facilities that would provide the United States with sources competitive with those now in operation in Europe and Japan. This study also eloquently summarized the broad uses and future opportunities for neutrons in science and technology.

In response to this national need, DOE-ER provided funds in FY 1996 and FY1997 to initiate the research and development (R&D) for such a source and complete a conceptual design report (CDR). To accomplish this task, the Laboratory organized a collaborative design effort involving ORNL, Argonne National Laboratory (ANL), Brookhaven National Laboratory (BNL), Ernest Orlando Lawrence Berkeley National Laboratory (LBNL), and Los Alamos National Laboratory (LANL). This collaborative approach was taken to access the best technical expertise available, to initiate a conceptual design process that made the most efficient use of the DOE work force and resources, to incorporate a number of previous feasibility studies by the collaborating laboratories, and to consolidate community consensus. In addition, memoranda of understanding have been signed with the European Spallation Source and several European laboratories to access research results and technology developments that could further leverage the SNS design effort.

The reference design for the SNS consists of a high-energy linear accelerator (linac) injecting into an accumulator ring that produces short bursts of protons at extremely high energies and power levels. These proton pulses will be directed onto a heavy metal target where, through the spallation process, neutrons will be produced, moderated, and guided into experimental areas for use in a wide variety of experiments. BNL, LANL, and LBNL are responsible for the accelerator system design, which will be coordinated by an accelerator design group at ORNL. ORNL is responsible for the coordination, installation, and operation of the new source; for project management; for conventional construction; for target design; and—with ANL—for experimental systems design. The neutron user community will be intimately involved throughout the life of the project to select the experiment systems and instrumentation and to ensure that the completed facility meets the community's needs.

The CDR for the SNS, which was completed in May 1997, contains more than 1800 pages of technical details and drawings. DOE-ER held a full validation review of the SNS CDR in June 1997. The review committee consisted of approximately 60 scientists, engineers, and business leaders from the United States and Europe. In addition, the SNS Steering Committee and an independent cost estimation team from DOE attended the review. The reviewers performed an in-depth assessment of the technical feasibility, scope, cost, schedule, and management of the SNS.

In its close-out briefing, the review team gave a strong endorsement of the SNS project. Conclusions and recommendations included the following:

- The review team enthusiastically endorsed the collaborative approach taken by ORNL for designing and constructing the SNS.
- The accelerator reference design choice, technology, upgrade paths, and neutron target were considered sound and well advanced.
- The reviewers estimated SNS costs to be within 2% of the CDR estimate.
- The proposed six-year construction schedule was considered aggressive.

- The experiment facilities group
  - endorsed target, moderator, beam lines, and facilities design;
  - concurred that a 60-Hz repetition rate was the correct frequency for the first target station, but noted that a second, lower frequency target was needed as soon as possible;
  - approved the plan for involving the neutron community in the selection and construction of the instruments for SNS; and
  - recommended more R&D on advanced instrument concepts for SNS.

This successful CDR review was an essential and important step to providing the information needed by DOE to continue the SNS project to completion. The project will receive an additional $23 million in FY 1998 to complete preparations for a construction line item request to the DOE and Congress for the FY 1999 budget. With continuing support from the science community, the SNS could be providing neutrons by the year 2004 or 2005.

4.1.3 • Joint Institute for Neutron Sciences

ORNL, UT, and the state of Tennessee have initiated plans for a Joint Institute for Neutron Sciences. This facility will enhance the utility of the SNS and the HFIR by providing meeting facilities, offices, laboratories, a communication center, and housing for scientists and engineers from universities, industries, and the international research community. It will also be a focus for expanding neutron science R&D with UT, other regional universities, and industrial collaborators and will serve as an interface and economic development gateway for outside access to ORNL's neutron science facilities. Funds included in the state of Tennessee's FY 1996 budget were used to begin the conceptual design of the Joint Institute for Neutron Sciences in preparation for a construction request in the coming years.

4.2 • Functional Genomics

The sequencing and mapping phase of the Human Genome Project should be complete early in the next decade. 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. In the new "post-genome" era that follows, an important focus of research will be how genes function. Biologists have been studying gene function for many years, but most of their research has been slow, very costly, and directed at single genes. Access to the powerful reagents from the genome program will change all of this. In this post-genome era, instead of studying only the function of individual genes, it will be possible to perform experiments in functional genomics—that is, gene function on a genome-wide scale.

There are many different approaches for studying gene function. One of the most useful ways to gain insight into the function of a gene is to turn the gene off or change its normal pattern of expression through gene mutagenesis. For example, when cancer develops because a gene is not functioning properly, it is straightforward to assign the cancerous function to that gene. In fact, it is through this approach that genes have been associated with major diseases in humans, such as Huntington's disease, cystic fibrosis, and breast cancer.

Mutations in the genes provide a molecular "tag" to help geneticists determine which gene in a region of a chromosome is the culprit in disease.

Because gene mutagenesis is such a useful way of studying gene function, it would be useful to generate new gene mutations on a genome-wide scale. For obvious reasons this cannot be done in humans. Therefore, genome researchers are turning to model organisms such as the mouse. Mice are anatomically and physiologically similar to humans in many important ways. Also, mice contain genes that are functional counterparts for most of the genes in humans. In fact, it is remarkable that, in several cases, a mutation in the mouse counterpart of a major human disease gene can cause essentially the same disease in mice as that observed in humans.

ORNL is directing a portion of its Laboratory Directed R&D (LDRD) funding to a new effort in functional genomics (see Sect. 6.3.1.1), which supports DOE goals in functionalizing the genome. The functional genomics program is building on ORNL expertise in mouse mutagenesis and incorporating many other Laboratory capabilities, including protein chemistry, structural biology, instrumentation, robotics, automation, and computer science. The interdisciplinary nature of this new program is the key to expanding ORNL's mouse mutagenesis capabilities to genome-wide proportions.

ORNL is positioning itself for the formation of a core functional genomics effort dedicated to the large-scale generation, phenotypic characterization, molecular analysis, and distribution of new mutations in the mouse. Reaching this goal will require a major increase in the rate at which new germ line mutations can be generated and screened for phenotypes that are caused by single and/or multigenic mutations. For scientists to be able to map and quickly identify these new mutations, new strategies are needed for high-throughput analyses of DNA fragments that are markers for specific sites on the genome. New approaches must be developed for detecting altered gene expression profiles in normal and mutant lines of mice. Also needed are innovative approaches for cataloging this new information and user-friendly tools for disseminating the information.

During the first year of this initiative, researchers in ORNL's Life Sciences and Chemical and Analytical Sciences divisions worked together to develop innovative approaches for conducting mouse mutagenesis experiments that could be applied on a genome-wide scale. Other investigators in the Chemical and Analytical Sciences Division developed new functional genomics applications for the award-winning "Lab on a Chip" technology that involve the detection of genome-wide molecular markers using the polymerase chain reaction. Other investigators in the Life Sciences Division, working with researchers in the Instrumentation and Controls Division, expanded their research on new miniaturized devices, called genosensors, which can be applied to the simultaneous analysis of hundreds and even thousands of genes from mutant mice. Efforts were also made to integrate state-of-the-art robotics capabilities into the existing biological efforts in the Life Sciences Division.

To organize all the new data generated in this collective effort, and to help develop a new user-friendly interface for this research to the outside world, investigators throughout the Laboratory are generating innovative bioinformatics capabilities that use ORNL's unique computing facilities. During the next several years, projects will incorporate ORNL capabilities in molecular biology, biochemistry, instrumentation, and automation. The Laboratory's institutional competency in integrated R&D and its capacity for interdisciplinary research are key elements in this process.

Among the resources available to support this initiative are the Intel Paragon XP/S 150 supercomputer, which can be used to analyze structure and sequences of the chemical building blocks of genes, and the HFIR, the world's most powerful research reactor and steady-state neutron source for determining the structure of biological molecules. The functional genomics initiative also provides opportunities to enhance the educational programs offered through the UT–Oak Ridge Graduate School of Biomedical Sciences.

ORNL's functional genomics initiative will support and functionally integrate the Laboratory's activities and resources, providing coordinated utilization of DOE's mouse genetics and mutagenesis capabilities. It will also enhance ORNL's ability to attract talented scientists interested in exploring the frontiers of molecular genetics in pursuit of the genetic basis of human disease.

ORNL will continue to seek a means of providing a new home for the Laboratory for Comparative and Functional Genomics, which is currently housed in an aging building at the Oak Ridge Y-12 Plant. The goal is to pursue ways of funding a new facility that will not have a negative impact on existing programs funded by the DOE-ER Office of Biological and Environmental Research.

Most biomedical research institutions are now positioning themselves for the post-genome era of functional genomics. Many other national laboratories are beginning to explore their options for applying their existing capabilities to functional genomics research. ORNL is uniquely positioned to play a major role in studying gene function through the large-scale generation and analysis of mutations in the mouse. By supporting ORNL's functional genomics initiative, DOE has the opportunity to enhance its scientific leadership in the application of mammalian mutagenesis to understand how genes function in normal development and in disease. In addition, opportunities for leverage are available through companies that are willing to support functional genomics activities at the level of millions of dollars per year. ORNL is developing a plan to work with the private sector to leverage DOE funds in support of functional genomics research.

4.3 • Distributed Computing at Teraflops Speeds

The use of computational tools is vital to most fields of science and engineering. These tools enable the creation of realistic models of physical situations, providing new insights into a host of scientific problems as computing speed and memory capacity continue to increase dramatically.

Computers that can perform trillions of floating point operations per second (teraflops, or TF) are a reality. Machines that are now running exceed 1 TF, 10-TF machines are being planned, and the path to 100 TF is now being defined. Contracts in place for systems at Los Alamos National Laboratory and Lawrence Livermore National Laboratory provide for 3-TF operations, well beyond the 0.2-TF capability now available through ORNL's Center for Computational Sciences (CCS). These systems will support DOE's Stockpile Stewardship and Management Program, which is designed to assure the reliability of the U.S. nuclear stockpile in the absence of nuclear weapons testing.

The computation, modeling, and simulation requirements of DOE's science and technology missions also extend into the multiple-teraflops realm.

- In the area of materials science, teraflops-level machines will make it possible to create meaningful models of the mechanical behavior of materials. The insights gained from these models should lead to improvements in structural integrity, strength-to-weight ratios, and material lifetimes, with the potential for improved fuel efficiency in automobiles, better performance of materials in harsh environments, and smaller and faster computer chips.
- Computational chemistry can apply multiple-teraflops systems to tasks such as describing the structure and interactions of nucleic acids (DNA and RNA) and understanding their relationships with proteins, with implications for biology and medicine; characterizing catalytic mechanisms in processes such as photosynthesis; and investigating the chemistry of the Earth's atmosphere and ozone layer.
- Computational fluid dynamics demands powerful computational resources for high-accuracy simulations of phenomena such as the wake and boundary layers of aircraft in flight, mixing regions of air and combustible materials in reactive flow, and mixing in rivers and estuaries.
- Quantum chromodynamics (QCD), widely accepted as the fundamental description of the strong interactions of elementary particle physics, requires large-scale numerical simulations to examine its predictions.
- Applications for multiple-teraflops systems in geosciences range from simulating earthquakes to predicting the fate of environmentally toxic materials in groundwater and managing water resources.
- The resolution of questions about global climate change will require multiple-teraflops capabilities to create accurate models of land, air, and oceans; account for the effects of pollution, greenhouse gases, and other factors; and provide accurate predictions that support scientifically sound technical and political decisions.

These areas represent a wide spectrum of requirements. In all of them, however, and in others of interest to DOE-ER, important problems that will require computational power in the range of 5 to 10 TF have been identified. In some areas, needs already extend beyond this range. Furthermore, processing power is only one part of a balanced system; a 5-TF system will also require

- 5 terabytes of computer memory,
- 7 petabytes (7×10^{15} bytes) of data storage capacity, and
- input-output (I/O) capacity of 200 gigabits per second.

In addition to the needed hardware, software challenges abound. Operating systems, I/O software, communications software and protocols, visualization systems, and network interfaces, together with applications software, must all work together with the hardware in solving problems.

ORNL proposes to provide a substantial component of the needed computational capability and to establish routine teraflops-level distributed computing for science and technology. In accomplishing these tasks, the Laboratory will draw on the resources of the CCS, which has been a leader in computational power during recent years, and on the expertise that it has gained in bringing the Intel Paragon computers of the CCS to very high levels of productivity by

- connecting its two largest Paragons over high-speed asynchronous transfer mode (ATM) OC-12 networks, creating a distributed machine with peak performance near 200 gigaflops, and

- working with Sandia National Laboratories (SNL) to link the Paragons at the two sites over ATM networks and apply the resulting distributed computing power to the solution of problems of extraordinary size and complexity.

The task of designing and developing a system in the 5-TF range and obtaining near-optimum performance from it will present major challenges, but the potential rewards are great. Such a system can contribute to the solution of problems now being addressed by DOE-ER programs and should also lead to new and effective ways of addressing these and more challenging future problems.

The ORNL-SNL partnership has led to innovative means of solving problems by linking supercomputers over high-speed networks. Extending this strategy into the multiple-teraflops regime, which is a key to effective application of DOE's computational resources, will require the development of networks operating in the range of 10 gigabits per second, roughly equivalent to OC-192 requirements. Extension of the distributed computing capabilities gained through this partnership to the multiple-teraflops range will also require significant efforts in such areas as massively parallel processing computers; seamless access; high-speed, secure networks; readily accessible data storage systems; and software and applications to support user needs.

To begin this process of providing multiple-teraflops computing capability for DOE-ER, ORNL proposes to acquire an innovative shared-memory machine being developed by SRC Computers, Inc. The plan is to procure a modest prototype machine in FY 1998 and carry out a comprehensive evaluation of this machine that includes assessing its performance on a broad spectrum of Grand Challenge–level codes in such areas as materials science, computational chemistry, computational fluid dynamics, QCD, geoscience simulations, and global climate change modeling. This evaluation will also include detailed studies of node interconnect strategies and systems and novel architectural features of the SRC machines.

If the results of the evaluation are satisfactory, as anticipated, a specification set will be written to procure a multiple-teraflops machine. The initial nodes of this machine will be delivered in FY 1999, with delivery to be completed in FY 2000. The requisite data storage and network peripherals to be purchased will be on a scale consistent with achieving a balanced computational environment. Funding projections are shown in Table 4.1.

With the development environment available through the ORNL CCS, the Intel Teraflops machine now being assembled at SNL (with a design goal of 1.8 TF), and the proposed teraflops-level machine at ORNL, the resources needed to attain an optimally effective multiple-teraflops environment for addressing an extensive range of science and technology applications will be ready for integration and deployment.

Table 4.1
Funding projections for Distributed Computing initiative by fiscal year
(in millions of dollars)

	1998	1999	2000	2001	2002
Operating	0.5	3	5	6	10
Equipment	1.0	12	20	12	8
Total	1.5	15	25	18	18

5 • Operations and Infrastructure Plans

Operations functions [i.e., functions involving managing the Oak Ridge National Laboratory (ORNL) and supporting the core programmatic and research functions] are carried out principally by the Laboratory's Central Management Offices and Operations, Environment, Safety, and Health (OES&H) Directorate. Since January 1, 1996, ORNL has been 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.

A Laboratory-wide reengineering effort, discussed in Sect. 5.1, was launched in March 1996 to improve ORNL's competitiveness. This effort includes a focus on recruiting and retaining outstanding scientific, engineering, and support talent; plans for ORNL's human resources (HR) activities are discussed in Sect. 5.2. Plans and activities in management practices are described in Sect. 5.3. Environment, safety, and health (ES&H) issues and plans are reviewed in Sect. 5.4.

5.1 Reengineering ORNL

ORNL has embarked on a broad-based reengineering effort aimed at improving both the cost-effectiveness and the operational effectiveness of the Laboratory. This activity complements a cost reduction/avoidance effort that has been in place since 1993 and has resulted in cumulative savings of over $130 million, with significant savings in Laboratory overhead,

program and office costs, and division burden. It is part of ORNL's continuing commitment to implementing the Department's Strategic Alignment Initiative.

Reengineering activities are focused on broad, cross-cutting issues that influence the overall effectiveness of the Laboratory. The emphasis is on placing decision making, authority, and accountability in the portion of the Laboratory best able to act. A high-level Reengineering Steering Committee guides the process.

Targets for reengineering include the following key areas.

- Our current information systems for financial management and HR have evolved over many years; at present, these functions are administered through a collection of more than 80 subsystems that are poorly integrated and that run on mainframe computers nearing the end of their useful lives. We are implementing the SAP R/3 system using a client-server architecture and are reengineering our business and HR processes to take advantage of the capabilities of the new system. We estimate that, in partnership with Lockheed Martin Energy Systems, Inc. (LMES), we will realize savings of $9 million to $14 million a year from implementation of the new system, with additional savings coming from reengineering of our processes. We are on target for implementing the new system by the beginning of FY 1999.
- The contract between DOE and LMER has been modified to incorporate "Work Smart" standards, and such standards have been defined for >85% of ORNL. Environment, safety, health, and quality (ESH&Q) procedures have been modified to reflect these standards. We are piloting a program to place responsibility and accountability for ESH&Q performance in the line organization. As part of the pilot, we are defining roles, responsibilities, expectations, resources, performance measures, and reward structures. We are placing compliance training in the compliance organization and are restructuring course content to reflect Work Smart standards.
- Our craft services are expensive primarily because of bureaucratic and organizational barriers that have developed over the years. We have chartered a number of reengineering teams co-chaired by members of our Plant and Equipment Division management and members of our craft unions. These teams are examining issues associated with transportation of workers to the work sites, availability of materials and spare parts, and customer service. Investments have also been made to open some specialized field shops and stores.
- ORNL has a reputation for being not very user friendly, primarily because of the complex bureaucracy that has evolved to deal with the various legal and administrative requirements for bringing people or money into the Laboratory. We have proposed a new Partnerships Office to collect all these activities in one place; the office will apply a caseworker approach to help guests and users access the Laboratory. We are also developing a new approach to use our intellectual property more effectively as a business program development tool.
- We have developed a number of reengineering recommendations aimed at streamlining our approaches to waste management and engineering design and construction. We believe that implementation of these proposals can produce cost avoidances of 25–40% in these areas.
- We recognize that if our reengineering efforts are to succeed, we must have HR practices that reinforce the change in culture—from a culture based on control of behavior to one based on personal accountability. We are making a major effort to redesign our performance management tools, including support staffing, pay/reward and recognition,

promotion, succession planning, and career development, to support this change. We are also developing new tools for dealing promptly with performance that falls below our standards. We will transfer most HR decision making from the HR organization to the line organizations.

The reengineered ORNL will be more cost-effective and more organizationally effective because individuals at all levels in the organization will understand what is expected of them, have the authority and tools to act appropriately, and accept accountability for their actions. Performance will improve, and costs will fall. Sections 5.2–5.4 provide details on these activities.

5.2 • Human Resources

As part of the reengineering process described in Sect. 5.1, a Human Resources Reengineering Team was chartered to develop a vision, an organizational philosophy, and a high-level implementation strategy for new HR tools, processes, and systems that will help ensure a long-term future for ORNL. The aim was to position ORNL to attract, retain, and motivate top people (both staff and guests) to carry out the Laboratory's missions.

The Human Resources Reengineering Team developed a set of recommendations and estimated that their adoption could lead to substantial cost savings compared to the FY 1995 baseline. Additional savings were projected to result from a new HR information system and from the use of a cafeteria-style benefits package.

ORNL's 1997 Salary Planning Program implements several of the team's recommendations. It enhances the competitiveness of ORNL's salaries, pays for performance, rewards "high-impact" performers, provides a disincentive for low performers, and adjusts salaries to midpoint faster. The program was reviewed by ORNL's senior managers, division directors, and office directors. DOE staff members worked with ORNL to achieve some specific goals. Further changes will be made to ensure that ORNL is able to recruit and retain the talented work force that it needs to execute its missions as a national laboratory.

The Laboratory continues to place high-level emphasis on equal employment opportunity (EEO) and affirmative action (AA), in addition to promoting recognition and appreciation for cultural diversity and inclusion and accommodating the needs of a changing work force. The Diversity Leadership Team, chaired by the Laboratory Deputy Director, continues to develop strategies to meet EEO/AA challenges.

ORNL has established a Training and Development Organization to support employee development. This organization will address issues in training programs, training infrastructure, records management, reducing training cost, World Wide Web–based training and education, leadership development, and skill-based training. This effort is also responsive to DOE 5480.20A, "Personnel Selection, Qualification, and Training Requirements for DOE Nuclear Facilities" (November 15, 1994).

ORNL's planning for HR will continue to respond to changes as the Laboratory moves through reengineering and adapts to future shifts in funding.

5.3 • Management Practices

5.3.1 • Business Management

Within the OES&H directorate, ORNL's business management function provides services in asset management, contract administration, cost savings, finance and budget, fleet management, mail services, material management, property management, Work for Others, and business interfaces with LMES, which formerly held the ORNL management and operating (M&O) contract and continues as M&O contractor for the Oak Ridge Y-12 Plant. LMES currently provides ORNL with services in benefits administration, procurement, and real estate.

5.3.1.1 • Cost Savings

For several years, ORNL has been working to implement cost efficiencies to reduce overhead and allocate more resources for research. The Laboratory's efforts were reinforced by a commitment to the Secretary of Energy to reduce costs by $18 million per year for five years, beginning in FY 1996.

ORNL's cost savings and avoidance program is supported by discussions with the DOE ORNL Site Office to obtain DOE objectives for the effort and to identify opportunities for efficiencies. The program includes project promotion and identification, project reporting and validation, and progress reports to the DOE ORNL Site Office and DOE-ORO. During FY 1996, ORNL identified over $20 million in cost savings and avoidances. Overall cost efficiencies for FY 1997 were in excess of $25 million, of which approximately $10 million resulted from new projects.

In FY 1996, ORNL overhead was $160 million. The overhead budget for FY 1997 was $158 million. This amount included $8.6 million for reengineering efforts, a $1.2 million increase in Laboratory Directed Research and Development (LDRD) funding, and other special items amounting to $2.8 million; when these amounts (which represent investments for the future) are subtracted from the total, it is evident that the net reduction in overhead operations for FY 1997 was nearly $15 million.

5.3.1.2 • Business Process Reengineering

As a key element of the reengineering effort (see Sect. 5.1), ORNL chartered a business process reengineering team to determine the most cost-effective and user-friendly financial and acquisition systems, processes, and high-level business rules for the Laboratory. The team included representatives from ORNL, DOE-ORO, and LMES. The team's recommendation to select SAP R/3, a commercial off-the-shelf system, as the enterprise-level business management system for ORNL and LMES was accepted, and implementation of the Delta Project to launch this system is under way. A pilot project began in early FY 1998, and application development, system testing, and training will be conducted during the year. The system is expected to be operational in early FY 1999.

5.3.2 • Performance Measurement

5.3.2.1 • Individual Performance

ORNL uses a performance planning and review system to evaluate individual job performance. Each salaried employee develops an annual performance plan with specific goals under the guidance of his or her supervisor. Supervisors annually appraise employee performance, using progress toward achieving goals as input for the appraisal.

The recommendations of the Human Resources Reengineering Team (see Sect. 5.2) included simplifying the performance management system; incorporating feedback from peers, direct reports, and matrix managers in addition to supervisors; eliminating quotas on performance ratings; and implementing new methods for rewarding high performers. Implementation of these recommendations has begun with ORNL's 1997 Salary Planning Package. The Enhanced Pay for Performance System for 1997 has three objectives:

- to better identify and reward high-impact employees,
- to communicate to those employees whose current salary is commensurate with or even exceeds their contributions, and
- to better identify, evaluate, and communicate with those employees who may not meet current or long-term organizational requirements.

ORNL has also introduced a Variable Pay Program intended to reward or compensate current-year achievements valued above and beyond expectations for individuals and teams. A pilot program for "360° feedback" will be launched in FY 1998.

5.3.2.2 • Division and Program Performance

Divisions and programs use strategic planning to set performance goals; performance is monitored internally and by advisory committees. Laboratory managers monitor research and development (R&D) productivity in each division.

5.3.2.3 • Laboratory Performance

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. For FY 1998, a set of Critical Outcomes, Objectives, and Performance Indicators has been developed, addressing six areas: Laboratory Sponsorship, Preparation for Spallation Neutron Source Project Line Item Start, ES&H Integration, Leadership and Management, Life Cycle Assets Management, and Diverse Institution. LMER reports bimonthly achievements toward accomplishment of these Critical Outcomes to DOE-ORO. Standards of performance are reviewed annually, and processes are in place for negotiating and establishing changes in performance measures.

5.3.3 • Quality Assurance Program

A formal Quality Assurance (QA) Program applies to all activities conducted by or for ORNL. QA staff in the OES&H Directorate support ORNL managers in the implementation of programs that foster effective R&D, accomplish ES&H objectives, and meet quality requirements. A system for tracking and trending issues and actions is in place, allowing both line operations and Laboratory management to be aware of ES&H commitments. This system includes access to "Lessons Learned." The QA program incorporates planning for prevention

of problems, quality control to assure conformance to requirements, and continuous performance improvement. Independent audit functions verify compliance with QA requirements and evaluate the effectiveness of QA programs. Self-assessments are conducted to evaluate performance and identify areas of improvement.

5.3.4 • Site and Facilities Management

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. ORNL has one of the oldest physical plants in the DOE laboratory system. Continuing efforts are required to enable extensive renovations and rehabilitation of general-purpose buildings and utility systems that have deteriorated owing to insufficient capital improvement funding for modernization and adaptation to changing program needs.

Increased DOE support for infrastructure improvements is improving the current situation. Several general-purpose office buildings have been constructed. A number of major construction line-item projects are under way, including roof replacement, sanitary sewer upgrade, and process waste treatment system upgrade. The Laboratory's chiller systems are being replaced and upgraded to meet high-priority compliance requirements related to replacement of chlorofluorocarbons (CFCs); this project will be complete by FY 2000. Upgrades to the steam distribution system are nearing completion. A plan to convert the steam plant from coal-fired with gas backup to gas-fired with oil backup has been developed. Implementation will begin in FY 1998 with the addition of a second gas-fired boiler through a line item project, and conversion should be completed by FY 2004.

ORNL is committed to good stewardship of its resources, both in management of existing facilities and in planning for future needs. A space chargeback system will be implemented in FY 1998. The cost of construction and upgrades is being addressed by the recently chartered Engineering Design and Construction Reengineering Team. The Laboratory will prioritize its needs and apply resources as they become available to ensure that maximum benefit is derived.

Within the OES&H Directorate, the Capital Assets Planning Group carries out capital asset management, facility planning, and space management for ORNL. This group develops the Integrated Facilities Plan, site development plans, and an infrastructure management plan (IMP) for ORNL. In addition, the Capital Assets Planning Group is ORNL's lead organization for DOE's Life-Cycle Asset Management process. The IMP serves as the primary document to support planning and budgeting efforts in this area.

5.4 • Environment, Safety, and Health

5.4.1 • ES&H Goals and Objectives

ORNL is committed to excellence in all activities and to cost-effective operation in compliance with all applicable ES&H laws and regulations.

The management contract between DOE and LMER establishes the fundamental ES&H expectations of DOE. The Laboratory has established planning goals and mechanisms to help achieve the ES&H strategies defined in the DOE Strategic Plan.

Consistent with the direction of the ES&H Management Planning Process described in DOE's FY 1998 ES&H Management Plan Guidance Manual, target milestones and

success indicators have been established for ES&H performance measures, objectives, and metrics. Risk-based prioritization of activities serves as the basis for planning and budgeting of all ES&H activities. These activities are described in the *Lockheed Martin Energy Research Corporation ES&H Management Plan for the Oak Ridge National Laboratory,* which is submitted annually to DOE in accordance with the DOE-LMER management contract.

The ES&H Management Plan will be modified and upgraded to incorporate the principles of the DOE Safety Management System Policy. The upgraded plan will describe ORNL's Integrated Safety Management System.

In response to the April 1997 report *Integrated Safety Management Evaluation of Brookhaven National Laboratory,* issued by DOE's Office of Environment, Safety and Health, a team was organized to review the status of integrated safety management (ISM) at ORNL, with the goal of assuring compliance with the guiding principles of ISM and benefiting from lessons learned. The team has submitted a report and action plan to ORNL's senior managers, and an implementation plan is being prepared.

5.4.2 • Current Conditions

5.4.2.1 • Regulatory Environment

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. Within the DOE-LMER management contract, ORNL has committed to several actions to improve its ES&H program and accepted specific responsibilities:

- ORNL has accepted oversight responsibility regarding health, safety, and environmental law compliance for the Laboratory and the Oak Ridge National Environmental Research Park.
- ES&H activities conducted under the contract are subject to the "Work Smart" standards as approved by DOE.
- ORNL has committed to significant progress toward achieving DOE Voluntary Protection Program (VPP) "Star" status and will report at least annually on its progress toward this commitment. An assessment of ORNL's status with respect to the VPP was completed in FY 1997.
- The contract also specifies ORNL compliance with all the requirements of the Clean Air Act, the Clean Water Act, and 19 other environmental laws and their applicable regulations; in addition, ORNL will assist DOE in compliance with other specified laws and executive orders, such as the National Environmental Policy Act (NEPA) and the Endangered Species Act.
- ES&H activities conducted under the contract are also subject to specified DOE policies and orders.

ORNL has made significant progress in the necessary and sufficient (N&S) process. The purpose of this process is to identify a set of ES&H "Work Smart" standards necessary to (1) ensure compliance with laws and regulations and (2) provide adequate protection to the environment, the workers, and the public at the lowest possible cost. Definitions of hazards associated with work conducted at ORNL have been developed and used as a primary basis

for developing the set of "Work Smart" standards included in the Laboratory's management contract.

5.4.2.2 • Operating Context

The diversity of ORNL's R&D and support activities creates challenges as well as opportunities for the Laboratory in the effort to apply ES&H goals and objectives in a manner that supports the mission and adds value to operational performance. Established in 1943, ORNL today is engaged in basic and applied R&D in all of DOE's major businesses. Although significant changes in operations are not currently expected, ORNL management recognizes the need to focus on full integration of ES&H considerations into its mission. Also of major importance is the need to institutionalize the budgeting prioritization process, taking into consideration both the risks of operation (to the environment, site personnel, and the public) and the need to effectively and efficiently conduct the activities necessary for mission execution.

With the expectation of decreasing ES&H funding and with the continuing emphasis on overhead reduction, ORNL is challenged to redefine approaches for providing a safe and compliant operating environment in which its mission may be accomplished more cost effectively. ORNL is working to integrate its ES&H management planning with other business planning processes.

Changes in ORNL's relationships with other DOE facilities in Oak Ridge also challenge program continuity and improvements. ORNL's affiliation with LMES is being managed so as to ensure continuation of services essential to both organizations. The evolving relationship with DOE under the DOE-LMER management contract requires that ORNL anticipate, define, and meet DOE expectations, supported by effective means of measuring and communicating its efforts.

5.4.3 • ES&H Plans and Initiatives

5.4.3.1 • Present ES&H Concerns

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 are described in Sects. 5.4.4 and 5.4.5.

ORNL 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 operates one reactor, the High Flux Isotope Reactor; several other reactors have been permanently shut down and are awaiting transition to the decontamination and decommissioning (D&D) program. 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.

5.4.3.2 • Plans for Ensuring ES&H Compliance

The ES&H Management Plan describes the approach used at ORNL to ensure the health and safety of employees and the public, protect the environment, and comply with applicable DOE policies and orders and other ES&H requirements. The plan documents the systems and processes used by ORNL to (1) establish and communicate ES&H expectations to the ORNL community, (2) identify and secure funding for ES&H activities using risk-based planning and priority setting, (3) conduct R&D activities and operations through integration of ES&H principles in work planning and execution, and (4) assess ES&H performance and provide feedback to promote continuous improvement. As noted, this plan will be upgraded to become the basis of the ISM Plan for ORNL.

5.4.4 • Environmental Management Activities

Environmental restoration and legacy waste management activities at ORNL are presently the line responsibility of the Environmental Restoration Division of the LMES Environmental Management and Enrichment Facilities Business Unit. Because LMES has elected not to participate in the competition for the management and integration (M&I) contract for environmental management of DOE's Oak Ridge facilities, a change in responsibilities will occur during FY 1998. ORNL will work with DOE-ORO to address the issues and explore the opportunities presented by this change.

The remedial action component of the Environmental Restoration Program addresses the investigation and remediation of contaminated sites and contaminated environmental media at ORNL. Environmental data for remedial sites are collected in cooperation with other efforts at ORNL (e.g., the Environmental Compliance Program) with support from technical staff in the Environmental Sciences Division, Energy Division, and other ORNL organizations to address contaminant transport in the complex hydrogeologic setting at ORNL. Efforts to evaluate and remediate environmental problems build on ORNL research efforts that are supported by DOE's Office of Energy Research and other basic science programs. The program also includes deactivation, surveillance and maintenance, and D&D (here decommissioning is demolition or reuse) of contaminated surplus facilities.

The strategy for implementing the ORNL Environmental Restoration Program includes the following steps:

1. Sites are prioritized for rapid actions on the basis of risk to human health and the environment. Rapid actions are taken to address contaminant releases and transport to off-site surface water and local groundwater. These must be consistent with likely future final actions. Monitoring at key locations quantifies and tracks contaminant releases and identifies major sources of contaminant release.
2. Remedial investigations are conducted to provide the information needed to formulate and implement final remedial actions. This step also includes working with stakeholders to establish land use objectives, conducting technology development activities, and performing feasibility studies.

3. Remediation is conducted to achieve the final goals for risk reduction and compliance with environmental regulations commensurate with planned or potential future land use.
4. Monitoring is continued at key locations to document the performance of remedial actions, evaluate the need for contingent actions, and identify remaining or new areas of concern.

5.4.5 • Waste Management

5.4.5.1 • Program Description

The ORNL Waste Management and Remedial Action Division (WMRAD) is responsible for operation of all waste management facilities at ORNL (except the sanitary sewage system) and for facility upgrades and construction of new waste management facilities. About 125 staff members are employed in the WMRAD. A number of other ORNL and LMES organizations provide support to WMRAD activities.

The waste management program at ORNL provides continuous collection, treatment, and discharge of gaseous wastes; treats 535 million liters (150 million gal) per year of liquid radioactive waste (excluding sewage); and manages about 6,200 m^3 (167,400 ft^3) per year of solid radioactive, hazardous, mixed, and sanitary/industrial wastes. Major waste management activities include comprehensive coordination of waste reduction; integrated strategic and long-range planning; upgrades of existing facilities and construction of new ones; performance assessments of solid waste storage areas and other waste disposal facilities; waste collection and certification; and waste treatment, storage, and disposal.

The corrective activities component of the program provides for implementation of the FFA requirements as they pertain to active low-level liquid waste (LLLW) tanks and tank systems. It also includes upgrades of the Bethel Valley and Melton Valley LLLW collection and transfer systems. Line-item projects include implementation of the active LLLW tank systems requirements of the FFA and completion of the Melton Valley Storage Tanks Capacity Increase Project.

Out-year activities in waste management include continued operation of waste treatment, storage, and disposal facilities, with several upgrades. The focus of future activities will shift toward off-site waste disposal at commercial and other DOE sites, rather than disposal at ORNL or on the Oak Ridge Reservation. Waste reduction will continue to be emphasized.

The ORNL Pollution Prevention (P2) Program addresses sanitary/industrial, radioactive, hazardous, and mixed waste generated at ORNL. The P2 Program performs the planning and reporting functions required by state and federal laws and DOE orders; provides coordination, training, and technical assistance to waste-generating divisions; provides funds (when available) to waste generators to help them reduce their waste generation; coordinates the sanitary waste recycling programs; spearheads affirmative procurement; runs an awards program; and tracks waste reduction.

The P2 Program also administers a program of awareness for pollution prevention, as required by DOE Order 5400.1. Each ORNL division has a P2 representative who acts as the P2 Program's point of contact with that division. The P2 Program will pursue a strategy with the following essential features:

- Maintain an organization that comprises management and staff representatives who continue to develop and administer the program.

- Continue to identify materials, wastes, discharges, and emissions to be targeted for reduction.
- Continue to develop methods for tracking program performance and progress.
- Continue to foster and encourage development of pollution prevention technologies, awareness of environmental problems, and a philosophy that includes pollution prevention.

The strategy focuses on four major elements:

- the evaluation of research and support operations for pollution prevention opportunities and associated projects, including R&D,
- pollution prevention promotional activities,
- tracking activities (including wastes and pollution prevention projects), and
- the exchange of information and technology.

5.4.5.2 • Waste Management Reengineering

In 1997, representatives of DOE, ORNL management, WMRAD, 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 was to identify ways in which the waste management process could be streamlined and improved to reduce costs while maintaining full compliance and customer satisfaction.

The reengineering team focused on eight aspects of the Laboratory's waste management program: pollution prevention, waste characterization, waste certification/verification, hazardous/mixed waste stream, generator/waste management teaming, reporting/records, disposal end points, and on-site treatment/storage. Process teams were assembled to conduct in-depth evaluations of each area. Each team produced a report documenting its findings and recommendations. The 80 process-specific recommendations generated by these teams were then consolidated into 15 overall recommendations. The reengineering team benchmarked a commercial nuclear facility, a commercial research facility, and a DOE research facility to validate its findings and to seek additional ideas for improvement.

The 15 recommendations add up to a vision for the reengineered approach: a "cradle-to-grave" process of waste management at ORNL. Key elements of this process are

- an integrated waste management/generator function that treats ORNL as a single generator for expert-based waste characterization and certification purposes;
- a waste management organization that recognizes the generators, DOE, and the incoming M&I organization as equally important customers;
- focused pollution prevention, followed by waste generation, collection, treatment, storage, and disposal operations that reflect more cost-effective commercial approaches and incorporate new technologies and outsourcing of services where appropriate to provide the least expensive solutions; and
- incorporation of new information management technologies into a more interactive waste management/generator structure to create a "seamless" Waste Management Information System.

With successful implementation of these recommendations, ORNL should be able to reduce its annual waste management cost by $10 million to $15 million.

6 • Enterprise Activities

The *Strategic Laboratory Missions Plan—Phase 1* of the U.S. Department of Energy (DOE) contains the following statement about the national laboratories: "The laboratories develop, maintain, and apply unique, world-leading science and technological facilities and capabilities, and collaborate with industry, universities, and other Federal laboratories to pursue the Department's missions, and make their capabilities available to others in the national interest." In executing these tasks, the Oak Ridge National Laboratory (ORNL) draws on institutional strengths in development and operation of national research facilities, research and development (R&D) integration and partnerships, technology transfer, and science education. Activities include

- integrated R&D;
- science and technology partnerships;
- activities through which ORNL develops new capabilities for meeting mission needs; and
- information and communication activities to ensure that the information needs of ORNL staff, DOE, and the public are met.

6.1 • Integrated R&D

ORNL focuses and leverages DOE resources through activities that cross traditional disciplinary, programmatic, and organizational boundaries and take advantage of the range of capabilities available at the Laboratory, at other DOE facilities in Oak Ridge, and at other national laboratories. Programs and centers provide the framework for integrating specialized capabilities and applying them to the needs of multiple sponsors, both within and beyond DOE. The activities described here crosscut the DOE business lines and involve partners and sponsors from both public and private sectors. Some are well established and extensive; others are just beginning. All have the potential to bring the Laboratory's resources to bear on significant national and global issues.

6.1.1 • Advanced Materials, Physical, and Neutron Sciences

6.1.1.1 • Crystal Growth

The growth of single crystals is critical to a number of DOE missions and activities. The Office of Basic Energy Sciences in DOE's Office of Energy Research supports programs in basic and applied aspects of advanced materials that rely on the unique properties of single crystals. Single crystals are also important in areas ranging from metallurgical science to the biological and health sciences. Single-crystal materials are used, for example, in activities

sponsored by the DOE Office of Defense Programs and the DOE Office of Energy Efficiency and Renewable Energy and in laser fusion research. The broad utility of single crystals in energy-related research is demonstrated by their recent application to pioneering studies of the welding and joining of commercially important materials such as stainless steel.

More generally, single crystals are vital to the operation of a wide range of electronic and optical systems used in the monitoring and control of energy-related systems, and their importance in modern high-technology systems continues to increase. This is particularly noticeable in the field of thin-film devices, since bulk single-crystal "substrates" are a requirement for the production of epitaxial (single-crystal-like) thin films. Extensive research programs in China and Europe attest to the importance of this area. In the absence of a coordinated U.S. commitment to crystal-growth science, the lead in this critical and enabling field is increasingly being assumed by institutions in other nations.

ORNL is unique in its combination of crystal-growth capabilities and extensive materials characterization capabilities, both of which are important elements of the Laboratory's distinctive capabilities in materials science. ORNL's work is internationally recognized and is characterized by a history of scientific successes dating back to the early 1950s, when essentially defect-free metal single crystals produced at ORNL were used in pioneering investigations of radiation-induced defects in solids. The present DOE commitment to crystal-growth R&D at ORNL and the Laboratory's crystal-growth capabilities (including some that are unique in the world) make ORNL the logical base on which to build a national program in this area.

These capabilities span a wide range of techniques (Czochralski growth, submerged-arc-fusion growth, float-zone growth, flux growth, Bridgman growth, chemical vapor transport, etc.). ORNL also maintains some unique capabilities for the growth of actinide-doped and other radioactive crystals, which were extremely important in past programs of fundamental research on actinide elements and may be applicable to developing DOE programs in fissile materials disposition. To build on existing programs and to increase the availability of its resources in this key area, ORNL proposes the National Center for Crystal Growth.

Initiative: National Center for Crystal Growth

The Oak Ridge National Laboratory (ORNL) proposes to establish a National Center for Crystal Growth to serve the crystal-growth research and development (R&D) needs of U.S. government and university programs in the physical, chemical, engineering, and biological sciences and to replace capabilities lost in the downsizing of industrial R&D programs.

Programmatic elements include

- a comprehensive pure and applied scientific research effort, focusing on oxide single-crystal growth, semiconductor crystal growth, metal and alloy single crystals, protein and other biological crystals, substrate development for film growth, and application of ORNL materials characterization capabilities;
- a national user program;
- an educational component supplying graduate research opportunities and fellowships, undergraduate traineeships, semester and summer programs, postdoctoral research fellowships, and faculty participation contracts and travel support;
- a crystal-growth information center and sample archive, with a searchable database for single-crystal growth that builds on Oak Ridge's information systems expertise; and
- a national archive of well-characterized, high-quality single-crystal research specimens, available on loan or a cost-recovery basis to U.S. investigators.

Physical elements include

- a state-of-the-art laboratory building;
- modern crystal-growth equipment covering every major crystal-growth method;

- a crystal-growth information system comprising a library, an on-line database, and an educational information resource; and
- a curated physical archive of well-characterized, "pedigreed" single-crystal research specimens whose properties are keyed to the database, as are references to previous investigations involving their use.

ORNL will launch this initiative with an effort to develop national support and funding and to build a dedicated constituency among crystal-growth scientists for the establishment of a central U.S. crystal-growth center. Drawing on funding from multiple agencies, this center would maintain an ongoing internal program of crystal-growth research; it would also function as a national user center for academic, industrial, and government scientists requiring support in various aspects of crystal growth.

Funding (see Table 6.1) will be sought from the Department of Energy (DOE); the Department of Defense (DOD), which supports various small crystal-growth efforts; the National Aeronautics and Space Administration (NASA), which supplies about $100 million a year for crystal growth, including protein crystal growth in space; the National Science Foundation (NSF); and possibly the National Institutes of Health (NIH), given the increasing importance of organic single crystals in biological research and in determining the structures of proteins and complex molecules. Support will also be solicited from companies engaged in single-crystal growth either as a primary business or in support of other products.

The development of the National Center for Crystal Growth will involve and rely on facilities and capabilities in ORNL's Solid State, Chemical and Analytical Sciences, Metals and Ceramics, Chemical Technology, and Instrumentation and Controls divisions. It would also involve the ORNL Engineering Technology Division, the High Flux Isotope Reactor (HFIR), and the Spallation Neutron Source (SNS). The Center would use (and develop new uses for) stable isotopes produced in ORNL's calutrons and employ specialized capabilities at the Oak Ridge Y-12 Plant (e.g., hot isostatic pressing and electroplating facilities.) Activities addressing the growth of organic and biologically important single crystals (e.g., protein single-crystal growth) would involve and supplement the programs of the ORNL Life Sciences and Environmental Sciences divisions.

The National Center for Crystal Growth will require a new dedicated laboratory building, roughly the size of the ORNL High Temperature Materials Laboratory, at a cost of $30 million to $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 direct Work for Others research contracts with private industry, by subcontracts in support of academic and DOD research, and by funds-in (and potentially other) cooperative R&D agreements. An education program will be developed and administered in conjunction with the Oak Ridge Institute for Science and Education and 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 the crystal-growth research activities at NASA's Marshall Space Flight Center and at the University of Alabama Center for Microgravity Research (both located in Huntsville, Alabama) provides additional opportunities for joint programs. Finally, major ORNL facilities such as the SNS and the HFIR Upgrade will place increasing demands on the Laboratory's capability to provide unique, high-quality single-crystal research samples to ORNL scientists and external users; the availability of a dedicated crystal-growth research facility should be extremely advantageous. 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 both of these neutron science facilities.

ORNL will seek innovative approaches to funding for the new laboratory building and the R&D program, with an emphasis on multiagency funding. The National Center for Crystal Growth represents an opportunity for agencies such as DOE, DOD, NASA, NSF, and NIH not only to leverage their research funds but also to provide increased opportunities for their grantees to carry out individual research programs. As a user facility, the proposed center will provide centralized, unique facilities for university, industry, and government-supported researchers to carry out the growth of single-crystal research specimens using the broadest possible range of state-of-the-art crystal-growth equipment.

Table 6.1
Projected funding for the National Center for Crystal Growth by fiscal year
($ in millions)

	1997	1998	1999	2000	2001	2002
Funding source						
DOE	0.1	0.2	1.0	5.0	4.0	3.0
Other agencies	0.0	0.2	2.0	25.0	16.0	11.0
Industry	0.0	0.0	0.5	0.5	0.5	1.0
Total	0.1	0.4	3.5	30.5	20.5	15.0

6.1.2 • Energy and Engineering Sciences

6.1.2.1 • Impacts of Energy Production and Use

ORNL's in-house energy programs, the largest and most broadly based among the DOE laboratories, span fundamental research, applied work, and technology development; technical assistance; and management of energy-related information. These programs link the physical, engineering, economic, and social sciences to create not only new science and technology but also such products as frameworks for improved performance in technology development and deployment, analyses of environmental externalities connected with energy production, and insights for planning and policy decisions related to major energy and environmental issues of national and global concern.

For example, the U.S. electric utility industry is restructuring from a collection of regulated monopolies into a competitive market. The electric transmission and distribution network is the means by which the advantages of this restructuring will be delivered to customers. Policies and procedures for governing network operation and the technologies used to construct, expand, model, and maintain the network are key elements in the new structure's ability to efficiently and fairly provide the promised benefits. In particular, unprecedented technical and operational challenges will be presented by the greater distances over which power transfers will occur, the number of diverse players pursuing competitive advantage, and the need to make maximum use of available transmission capacity. ORNL is working in partnership with industry, regulators, and customer groups to evaluate and optimize the performance of the new industry model, apply advanced mathematical and computational tools to system analysis and control, and develop leading-edge technologies for the next generation of transmission and distribution hardware.

6.1.2.2 • 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's Office of Energy Efficiency and Renewable Energy, 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 the U.S. Department of Transportation, the U.S. Environmental Protection Agency, the Department of Commerce, the Bureau of the Census, and the U.S. Department of Defense.

The Tennessee Transportation Coalition, which was formed by ORNL and its principal governmental, academic, and industrial partners in the region to pursue important opportunities in transportation research, 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 UT's Knoxville campus 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. A recent 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.

6.1.2.3 • Unexploded Ordnance

Unexploded ordnance (UXO)—a category encompassing land mines, ordnance from past military conflicts, and munitions at testing facilities—represents a serious global problem. The U.S. Department of State estimates that 85 million to 100 million antipersonnel mines, which can remain active for decades, are in place in 70 countries. Millions of square meters of land, primarily in rural areas, are affected. The United Nations estimates that 2 million new antipersonnel mines are laid each year during internal and regional conflicts. About 100 million more land mines reside in national stockpiles.

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.

There is a critical need to accelerate the worldwide clearing of UXO. Domestically, the United States faces a serious and costly challenge in locating and cleaning up large tracts of land and coastal areas that have served as training grounds for troops or testing 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.

The scope of the UXO problem spans five major mission areas: countermine (CM) technology, UXO disposal, humanitarian demining, active range clearance, and UXO environmental remediation. While technical requirements for each area may differ, technology is needed in all areas. R&D is needed to improve current detection and removal technology. 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).

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 both by DOE and by the Department of Defense (DOD) and other agencies has resulted in a variety of technologies that could be useful in mine detection and clearance. 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 Sandia National Laboratories to organize the ten major DOE laboratories into an Interlaboratory UXO/CM Task Force. This Task Force is working to coordinate collective DOE R&D capabilities and to facilitate the exchange of information on the UXO/CM 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 ten major laboratories) to participate in DOD's UXO Clearance Steering Committee. In addition, the Task Force drafted a memorandum of understanding (MOU) for cooperative DOD/DOE UXO/CM programs. This MOU is still under review. Follow-up coordination meetings between the two agencies have been held each month since the summer of 1996. 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.

Initiative: Disposal of Unexploded Ordnance

Technologies developed by Department of Energy (DOE) laboratories can be used to detect, mark, remove, and dispose of UXO and land mines. These technologies could contribute significantly to domestic and international demining efforts. Several U.S. and international governmental agencies, as well as nongovernmental organizations (NGOs), are prominent in demining efforts: the Department of Defense (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. DOE technology could complement the efforts of these agencies. Recommended thrust areas are listed in Table 6.2.

DOE will establish a budget line item in FY 1998 and beyond for a cooperative research, development, 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, the initiative will be coordinated by the Office of Nonproliferation and National Security 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/CM Task Force led by the Oak Ridge National Laboratory (ORNL) will play a key role in conducting the cooperative ordnance R&D program. Resource projections for ORNL participation in the UXO/CM initiative are shown in Table 6.3.

Table 6.2
Recommended thrust areas for UXO initiative

	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 6.3
Funding projections for UXO initiative by fiscal year
($ in millions—BA)

	1997	1998	1999	2000	2001	2002
Operating	0.2	2.0	4.0	8.0	10.0	10.0
Capital	0.1	0.2	0.2	0.3	0.3	0.3
Total	0.3	2.2	4.2	8.3	10.3	10.3

6.1.3 • Life Sciences and Environmental Technologies

6.1.3.1 • 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 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.

6.1.3.2 • Global Change

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 that brings together the Laboratory's extensive resources in environmental research, technology development, and integrated assessment.

Initiative: Global Science and Technology

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 research and development (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 (a major contributor to global climate change) from Federal sources; and regular scientific and economic reviews to ensure that policy-makers have the best possible information on climate change.

The Department of Energy (DOE) will play a major role in addressing this challenge. DOE programs in global change research, development of 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.

The Oak Ridge National Laboratory (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 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.

1. National Technology Portfolio

ORNL will continue the development of a national technology portfolio for reducing greenhouse gas emissions. A recent study co-led by ORNL, in collaboration with 10 other national laboratories, cataloged ≈50 technology pathways with significant potential for reducing greenhouse gas emissions. ORNL also led a multilaboratory effort 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 provide further information that can be incorporated into assessments of technology cost and performance; these in turn will provide a basis for technology selection and deployment.

ORNL will apply its expertise in research, technology development, and cross-cutting technologies to enhance or develop greenhouse gas

reduction technology pathways as identified in the 11-laboratory study. This effort may include 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 Bio-Energy Alliance 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 Bio-Energy Alliance will develop, apply, and deploy cross-cutting 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. 6.1.3.4) will be part of this effort.
- Improved fuels. The use of fossil fuels to meet most of the nation's energy needs will continue into the next century. The DOE 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. In developing effective fuel switching alternatives. ORNL plans to evaluate methods for producing methane from methane hydrates, addressing 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. ORNL's comprehensive buildings technology program will examine means of reducing electricity use, reducing the use of energy required for space and water heating and other domestic purposes, and expanding the potential for on-site generation of electricity. ORNL-generated improvements in the energy efficiency of equipment, appliances, and building envelopes 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 presents significant opportunities and challenges for advanced technologies to reduce greenhouse gas emissions. Opportunities lie in the continuous improvement of conventional vehicle technologies; in new 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 work with DOE and other federal agencies to develop a hybrid electric vehicle program plan to support the 21st Century Truck Initiative, with the aim of significantly reducing carbon dioxide emissions from new trucks. ORNL will also seek to expand its supporting role in the Partnership for a New Generation of Vehicles (PNGV) into the next phase: PNGV-2. In addition, ORNL's lead laboratory designation in combustion engine, alternative fuels, and emissions technology will be expanded to support the DOE light-duty vehicle program to develop by 2004 the enabling technology to encourage significant dieselization of Class 1 and 2 trucks.

- 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. The primary emphasis in ORNL's materials degradation work will be on pressure vessels; piping, pumps and valves; and concrete structures. In generation optimization, work will focus on using digital technologies to replace less reliable safety and control systems and on reducing uncertainties in operational parameters with advanced instrumentation, allowing operation at higher power levels.

2. 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 assessment takes shape during FY 1998 and FY 1999, ORNL will seek leadership roles in a number of regional and national activities. Planning for FY 1998 suggests several areas in which ORNL's experience would benefit regional assessments and national integration activities. Proposed areas of concentration in FY 1998 include the following.

- Coordination 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.
- Integration and coordination of the Southeast region assessment, one of about 10 regional assessments. ORNL will seek appropriate roles in this assessment, which will probably comprise several subregions (coastal, Appalachian, mid-Atlantic, etc.). Because of the existing network of assessment expertise in the Southeast, a concerted effort is under way to use the Southeast assessment as a model for other regions. ORNL will work with DOE and other federal agencies to expedite the Southeast assessment process and to demonstrate an integrated assessment process that captures multiple stakeholder perspectives.
- Support for a national synthesis of the regional assessment studies and for the establishment of a national technology leadership team to help focus the regional and national assessments. ORNL stands ready to assist 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 and the Walker Branch throughfall displacement experiments), (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.

3. Technology Strategy Formulation

ORNL will integrate the results of tasks 1 and 2 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. 2.3.3.1); measurement science and sensor development; and analysis of policy, energy, and human systems. Funding (see Table 6.4) is sought from the Office of Biological and Environmental Research in the DOE Office of Energy Research; the DOE Office of Energy Efficiency and Renewable Energy; the DOE Office of Fossil Energy; and the DOE Office of Nuclear Energy, Science and Technology.

Table 6.4
Funding projections for Global Science and Technology initiative by fiscal year
(in millions of dollars)

	1998	1999	2000	2001	2002
Operating					
Office of Energy Efficiency and Renewable Energy	2.0	10.0	15.0	15.0	15.0
Office of Energy Research	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	4.0	6.0	6.0	6.0
Equipment	0.1	0.1	0.3	0.3	0.5
Total	3.2	21.6	31.8	34.8	38.0

6.1.3.3 • Isotope Production

ORNL applies unique capabilities and facilities to carry out (1) R&D on isotope materials and applications; (2) development of isotope production processes and products; (3) specialty production of custom isotopes and isotope product materials for research in medicine, nutrition, biology, geology, physics, chemistry, and environmental sciences; (4) production of isotope products for crucial national needs; and (5) technology transfer of isotope production processes and products to commercial industries. 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, as well as other critical national needs. 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.

This capability is essential in areas such as ^{233}U utilization and operations. ORNL is the principal DOE site for storage of this fissile material, with inventories comprising approximately 1.2 Mg of ^{233}U and mixed $^{233}U/^{235}U$. These materials were produced during the 1950s and 1960s to investigate the ^{233}U–thorium fuel cycle for nuclear power production. ORNL was the center for much of the Atomic Energy Commission's work on thorium reactors, including the homogeneous molten salt breeder reactor and gas-cooled reactor concepts. The ^{233}U for the light-water breeder reactor demonstration was purified and converted to uranium dioxide at ORNL in the mid-1970s. Since completion of these programs, the fissile material has been maintained in storage, and limited quantities have been used for research and defense missions. DOE-DP currently has responsibility for the storage facility (Building 3019) and for the ^{233}U material at ORNL.

Although inventories have been relatively inactive during the last decade, several developing opportunities signal renewed activity in ^{233}U utilization and operations:

- Cancer therapy. Recent interest in alpha emitters for cancer therapy has led to the separation of ^{229}Th from the ^{233}U inventory at ORNL. The ^{229}Th (7340-year half-life) is being

used as a generator of ^{213}Bi (45.6-minute half-life) in clinical trials at the Memorial Sloane-Kettering Cancer Center.

- Molten Salt Reactor Experiment (MSRE) remediation. The MSRE Remediation Project, which is recovering ^{233}U from the 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 DOE Implementation Plan for DNFSB Recommendation 97-1, "Safe Storage of Uranium-233," is expected to accelerate the planned inspection, chemical stabilization, and repackaging of selected ^{233}U materials stored in Building 3019.
- Thorium nitrate stabilization. The Department of Defense 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.

These activities, which are sponsored by several DOE offices, present an opportunity to apply and expand the capabilities at ORNL for biomedical research, actinide and transuranic separations technology, fluoride and molten salt chemistry, materials technology, and fissile material stabilization and disposition.

6.1.3.4 • 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 DOE programs in the Offices of Energy Research; Nuclear Energy, Science and Technology; Environmental Management; Energy Efficiency and Renewable Energy; and Fossil Energy. 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.

Initiative: Separations Science and Chemical Processing

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 research and development (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.

The separations and chemical processing capabilities of the Oak Ridge National Laboratory (ORNL) support several offices in the Department of Energy (DOE): Energy Efficiency and Renewable Energy (DOE-EE); Energy Research (DOE-ER); Environmental Management (DOE-EM); Fossil Energy (DOE-FE); and Nuclear Energy, Science and Technology (DOE-NE). Although a core of funding exists, these programs have no central facilities and little integration.

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 and the Oak Ridge Y-12 Plant.

- 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 advanced inorganic membrane technology efforts at Y-12 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 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 expected to be 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 in the existing properties group are highly regarded and actively consulted by the petroleum industry; the formation of the CSCP will create a wider audience for their capabilities.

The CSCP will be expanded as quickly as possible 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 have been initiated to establish working agreements in separations with the University of Tennessee and the University of Texas.

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 6.5. Resources are sought from DOE-ER (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 other sponsors.

Table 6.5
Funding projections for Separations and Chemical Processing initiative by fiscal year
(in millions of dollars)

	1998	1999	2000	2001	2002
Funding source					
DOE					
Office of Fossil Energy	0.2	1.6	2.0	2.0	2.0
Office of Energy Efficiency and Renewable Energy	0.1	0.4	0.6	1.0	1.5
Office of Energy Research	0.0	0.2	0.3	0.3	0.4
Industry	0.2	0.6	1.0	1.5	2.0
Department of Defense	0.0	0.4	0.6	0.6	0.6
Total	0.5	3.2	4.5	5.4	6.5

6.1.4 • Computing, Robotics, and Education

6.1.4.1 • Robotics

ORNL performs R&D, demonstration, and application of remote systems, robotics, teleoperation, and related aspects of intelligent machines through interdisciplinary programs for DOE, the Department of Defense (DOD), and other sponsors. Much of this work is conducted at the Center for Engineering Systems Advanced Research. As a member of the DOE Alliance for the Advancement of Robotics Technology, ORNL 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 proposed initiative on disposal of unexploded ordnance (see Sect. 6.1.2.3) will draw on ORNL robotics and remote systems capabilities.

6.1.4.2 • 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 Office of Computational and Technology Research in DOE's Office of Energy 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 to "explore ideas and prototype tools for advanced data management concepts" 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) provides a means for the Laboratory to team with universities, other laboratories, and industry partners to build capabilities in basic and applied research for telepresence and collaborative environments. The mission of the CTRC is to advance meta-modeling languages to provide the foundation for the three layers of a real-time collaborative environment: (1) distributed, mobile software libraries and intelligent agents; (2) semantic modeling; and (3) real-time collaborative computing.

The CTRC builds on and leverages ORNL expertise gained in projects such as the Collaborative Management Environment (CME), the High-Performance Computational Engine for Analysis of Genome, Electronic Notebooks, and data mining and in existing interactions with universities, industry, and agencies other than DOE.

- Groups at ORNL and Carnegie Mellon University have written an initial proposal to work together on collaborative technologies and information systems.

- ORNL and DynCorp have worked together on the CME and are planning to set up a security access demonstration between DynCorp's Information and Engineering Technology Group and the CTRC.
- The chief of the COE Branch has expressed interest in working with ORNL on collaborative technologies research.
- The CTRC has submitted several proposals to the Army, the Navy, and DARPA for projects that include health information warfare and disaster relief collaborative technologies.

Work is under way to identify additional partners and develop a strategic plan for the CTRC. The CTRC will also prepare a number of workshops on enabling collaborative technologies as a means of advertising its presence in this arena and showcasing the highlights of current efforts.

The CTRC is available to assist DOE in collecting, evaluating, filtering, organizing, and disseminating software and information produced by the DOE 2000, Accelerated Strategic Computing Initiative, Grand Challenge, and other programs and in providing the building blocks for a collaborative environment. Capabilities developed by the CTRC will support DOE needs in science and national security and will also have broad applicability in education, business, and entertainment.

6.2 • 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.

The ORNL Office of Science and Technology Partnerships (Partnership Office) is the focal point for cooperative interactions between ORNL and outside groups or individuals. The Partnership Office serves as the primary contact for the designated user facilities at the Laboratory, provides assistance with the entrance and approval procedures for both domestic and foreign national assignments, negotiates user agreements, provides support services for research guests, and manages programmatic and approval processes for cooperative R&D agreement (CRADA) activity. Educational activities are coordinated through the Office of University and Science Education.

6.2.1 • 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, minority educational institutions (MEIs), and area primary and secondary schools. The Oak Ridge Centers for Manufacturing Technology (ORCMT), a cooperative effort of ORNL and the Oak Ridge Y-12 Plant, provides a mechanism for industry to access ORNL resources; many companies using this mechanism are also 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.

6.2.1.1 • 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 well over $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. Joint institutes (e.g., in biological sciences, computational sciences, energy and environment, heavy-ion physics, and molecular-based engineering and science) and graduate programs are additional tools for combining the resources of these institutions for research and education. One notable new partnership is the new National Transportation Research Center described in Sect. 6.1.2.2.

ORNL interacts extensively with 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), and the Advanced Industrial Concepts Materials Fellowship Program. ORNL also administers 23 subcontracts with MEIs, representing commitments of $760,763.

6.2.1.2 • 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. A new Mentor-Protégé Program provides a mechanism for Lockheed Martin Energy Research Corporation (LMER), ORNL's managing and operating (M&O) contractor, 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.

The Partnership Office is also working to encourage more interaction with small businesses. Much of this activity is expected to occur in the technical assistance area, where the Partnership Office will work closely with the Lockheed Martin Energy Systems, Inc., (LMES) Technical Assistance Programs.

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. At the end of FY 1997, ORNL's cumulative total for CRADAs was 234 (not including joint ORNL/Y-12 projects), representing commitments of more than $400 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. ORNL is currently involved in four AMTEX CRADAs. The Partnership for a New Generation of Vehicles also presents opportunities for cooperative projects that involve programs in DOE's Offices of Energy Research, Energy Efficiency and Renewable Energy, and Defense Programs. ORNL is also 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's Office of Energy Efficiency and Renewable Energy.

6.2.2 • 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 1996, the Partnership Office supported 4150 assignments of scientists and engineers from universities, industries, and other federal institutions. Of this number, 1219 were industrial guests. Many of these guests carry out R&D at one of ORNL's designated user facilities.

6.2.3 • Technology Transfer

Through the Partnership Office and the ORNL Office of Technology Transfer, the Laboratory 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 director of the ORNL Office of Technology Transfer serves in the same capacity for LMES, facilitating the integration of capabilities across the Oak Ridge complex.

The Office of Technology Transfer continues to promote the licensing of new technologies and the effective management of intellectual property. In FY 1997, 43 patents were issued and 31 licenses were executed.

6.2.4 • Science Education

ORNL actively supports scientific and technological education by engaging students and faculty at all academic levels throughout the nation 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. ORNL's educational focus complements that of degree-granting institutions.

6.3 • Developing Strengths for Mission Needs

6.3.1 • 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 1998 LDRD funds, the Laboratory's senior managers emphasized two research areas linked to major Laboratory initiatives: functional genomics and neutron science and technology. They also announced their intention to seek high-quality proposals that will enhance ORNL's capabilities for carrying out DOE missions, requesting proposals that focus on ORNL's role as a primary performer of DOE-sponsored research in basic energy sciences, energy efficiency, biological sciences, environmental science and technology, nuclear physics, and high-performance computing.

6.3.1.1 • Functional Genomics

In support of the major Laboratory initiative in functional genomics, $2 million of FY 1998 LDRD funding is earmarked for new projects in this area. The second year of this program will build on the accomplishments of the first through the development of innovative strategies for gene function research. Areas of particular interest include

- development of innovative procedures for comparing the mouse and human genomes for the purpose of identifying genes and regulatory elements on the DNA;
- development of additional approaches for producing a series of different kinds of mutations in each gene in the mouse in a cost-effective manner and on a genome-wide scale;
- generation of innovative techniques for screening large numbers of mutagenized mice for a broad spectrum of phenotypes;
- identification and analysis of sequence variations within and among species to study normal and disease states in humans and mice;
- analysis of expression of gene products (RNA and/or proteins);
- analysis of the biological role that gene products play within the cell; and
- development of innovative procedures for efficiently studying multigenic traits in mice.

6.3.1.2 • Neutron Science and Technology

In support of the major laboratory initiative in neutron sciences, the area of neutron science and technology is receiving special emphasis. Up to $1 million in LDRD funds is to be awarded for innovative projects in four research areas:

- new instrumentation and data visualization techniques that will take advantage of upgraded or new steady-state cold sources and short-pulse sources;
- areas of research (soft materials, small-angle scattering, structural biology, low-energy excitations) appropriate for new cold neutron capability at the High Flux Isotope Reactor (HFIR);

- moderators, beam optics, and Monte Carlo simulations for pulsed sources; and
- advances at the frontiers of neutron-based science made possible by the Spallation Neutron Source and the upgraded HFIR.

6.3.2 • 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.

6.4 • Information and Communication

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 (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.

When management of ORNL was transferred from LMES to LMER, the Laboratory elected to acquire its own core information management and information technology services, which were previously provided by LMES. These services are now provided by the ORNL Computing, Information, and Networking Division, primarily by selected staff transferred from LMES.

To ensure that these services address the concerns of ORNL staff, several customer committees exist; these 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.

Further details about ORNL's current strategies in these areas can be found in the ORNL *Strategic Plan for Computing,* which is reissued every few years.

6.4.1 • Scientific and Technical Information

Scientific and technical information is a primary product of ORNL's R&D efforts. As a unique national resource, it must be managed wisely throughout 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 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.

6.4.2 • Public Information and Outreach Activities

Communication of information about the Laboratory's programs, activities, and staff to the public is a high priority. Programs are in place to address the needs of both the general public and the "internal public"—ORNL employees.

Information products include the *ORNL Review,* the Laboratory's R&D magazine; frequent press releases describing activities at ORNL; and a news update service available through a toll-free telephone number. All of these information products are also available on the Web, in support of ORNL's plans to use this tool for communication about its research, technology, products, and services. Communications designed specifically for the internal public include a daily Web feature, "ORNL Today"; *Ridgelines,* a monthly newsletter for ORNL and LMES employees; and periodic Laboratory-wide meetings, which have been used to transmit information about ORNL's reengineering effort.

ORNL hosts family and community days and encourages members of the community to visit. In May 1997, ORNL hosted a Take Your Child to Work Day and a Community Day. Regularly scheduled breakfasts are held with elected officials from neighboring communities to exchange information and showcase ORNL's research activities.

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 tours, offered from March 1 through October 31, include a commentary on the city of Oak Ridge, the east end of the Oak Ridge Y-12 Plant, and ORNL.

Tours serve to educate local, regional, and national groups about DOE-sponsored research and technology. They are also expected to help increase science literacy and to serve as a means of obtaining feedback on how Oak Ridge is perceived by the public.

Laboratory staff participate in educational fairs, environmental fairs, and other community events. 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.

6.4.3 • Administrative Information

ORNL has initiated a process to replace most core business applications with a single commercial off-the-shelf product from SAP. As discussed in Sect. 5.3.1.2, the implementation of this system is being conducted by a joint ORNL/LMES reengineering team.

ORNL also 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

- moving to standards-based desktop electronic mail systems (nearly complete);
- using the Web for ORNL directives (complete);
- using the Web as the preferred interface for forms and business applications (well along);
- support for 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.

6.4.4 • 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 goals directed toward improved information resource management (IRM).

The Laboratory's objectives for a coordinated IRM program include

- increased desktop access to information via Internet technologies;
- acquisition or development of tools, techniques, and applications that support the evolving information needs of ORNL;
- maximum participation in deployment of corporate applications to enable appropriate implementation for ORNL;
- efficient records management via efforts now under way to inventory and capture key attributes of archival records into electronic retrieval systems; and
- enhanced electronic distribution of documents (i.e., cradle-to-grave electronic publishing and dissemination).

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. Construction funding for the Spallation Neutron Source is not included in these projections.

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)

	1996	1997	1998	1999	2000	2001	2002
DOE effort	448.0	458.3	561.4	561.0	559.5	561.0	561.0
Work for others	64.2	75.1	82.4	81.3	81.3	81.3	81.3
Total operating	512.2	533.4	643.8	642.3	640.8	642.3	642.3
Capital equipment	18.1	8.1	27.3	35.1	22.5	20.1	20.1
General Plant Equipment (GPE)	3.3	4.3	7.1	7.1	7.1	7.1	7.1
Construction	8.8	6.3	6.8	9.0	1.6	0.0	0.0
Total ORNL	542.4	552.1	685.0	693.5	672.0	669.5	669.5
Proposed construction	—	1.6[a]	10.3	59.0	12.1	3.1	3.1
Total projected funding	—	553.7	695.3	752.5	684.1	672.6	672.6

[a]Authorization for spending these funds has not been received.

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

	1996	1997	1998	1999	2000	2001	2002
Technical personnel, direct DOE effort	1194.8	1447.5	1507.6	1477.7	1474.2	1478.2	1478.2
Technical personnel, Work for Others	304.4	330.0	321.1	307.3	307.3	307.3	307.3
Total technical direct personnel	1499.2	1777.5	1828.7	1785.0	1781.5	1785.5	1785.5
Other direct	641.1	478.2	535.9	549.8	548.5	549.8	549.8
Total direct personnel	2140.3	2255.7	2364.6	2334.8	2330.0	2335.3	2335.3
Indirect personnel	2185.0	2150.0	2100.0	2000.0	2000.0	1950.0	1950.0
Total ORNL personnel	4325.3	4405.7	4464.6	4334.8	4330.0	4285.3	4285.3

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

	1996	1997	1998	1999	2000	2001	2002
Science and Technology Programs							
Office of Energy Research							
Operating expense	149.1	172.7	258.0	261.9	261.9	261.9	261.9
Capital equipment	8.6	7.1	19.9	27.9	18.2	15.8	15.8
General Plant Equipment (GPE)	3.3	4.3	7.1	7.1	7.1	7.1	7.1
Construction	6.3	6.3	6.8	9.0	1.6	0.0	0.0
Proposed construction	0.0	0.0	8.4	57.0	12.1	3.1	3.1
Total	167.3	190.4	300.2	362.9	300.9	287.9	287.9
Energy Programs							
Office of Energy Efficiency and Renewable Energy							
Operating expense	72.8	79.4	95.2	91.4	91.4	91.4	91.4
Capital equipment	0.9	0.0	1.9	2.1	2.1	2.1	2.1
Total	73.7	79.4	97.1	93.5	93.5	93.5	93.5
Office of Nuclear Energy, Science and Technology							
Operating expense	17.2	18.9	15.7	18.7	20.7	20.7	20.7
Capital equipment	0.5	0.1	4.6	3.3	0.4	0.4	0.4
Total	17.7	19.0	20.3	22.0	21.1	21.1	21.1
Office of Fossil Energy							
Operating expense	7.6	7.2	7.5	8.0	8.0	8.0	8.0
Energy Information Administration							
Operating expense	0.0	0.1	0.1	0.1	0.1	0.1	0.1
National Security Programs							
Office of Defense Programs							
Operating expense	11.3	11.8	15.2	14.9	14.9	14.9	14.9
Capital equipment	0.5	0.0	0.5	1.4	1.4	1.4	1.4
Proposed construction	0.0	1.6	1.9	2.0	0.0	0.0	0.0
Total	11.8	13.4	17.6	18.3	16.3	16.3	16.3
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	4.3	10.1	13.0	10.0	6.5	8.0	8.0
Environmental Management Programs							
Office of Environmental Management							
Operating expense	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	2.5	0.0	0.0	0.0	0.0	0.0	0.0
Total	2.5	0.0	0.0	0.0	0.0	0.0	0.0
Office of Civilian Radioactive Waste Management							
Operating expense	(0.1)	0.0	0.1	0.2	0.2	0.2	0.2
Office of Environment, Safety, and Health							
Operating expense	12.6	11.0	10.1	10.1	10.1	10.1	10.1

Table 7.3
(continued)

	1996	1997	1998	1999	2000	2001	2002
Other DOE Programs							
Office of Policy, Planning and Program Evaluation							
Operating expense	0.5	0.7	0.4	0.5	0.5	0.5	0.5
Federal Energy Regulatory Commission							
Operating expense	0.1	0.8	1.0	1.0	1.0	1.0	1.0
DOE funding from Lockheed Martin Energy Systems central organizations							
Operating expense	154.0	133.5	135.2	134.7	134.7	134.7	134.7
Capital equipment	4.5	(0.2)	0.0	0.0	0.0	0.0	0.0
Total	158.5	133.3	135.2	134.7	134.7	134.7	134.7
Subtotal DOE Programs							
Operating expense	429.5	446.2	551.6	551.6	550.1	551.6	551.6
Capital equipment	15.0	7.0	26.9	34.7	22.1	19.7	19.7
General Plant Equipment (GPE)	3.3	4.3	7.1	7.1	7.1	7.1	7.1
Construction	8.8	6.3	6.8	9.0	1.6	0.0	0.0
Proposed construction	0.0	1.6	10.3	59.0	12.1	3.1	3.1
Total	456.6	465.4	602.7	661.4	593.0	581.5	581.5
DOE Contractors and Operations Office							
Operating expense	17.4	10.9	9.1	8.8	8.8	8.8	8.8
Capital equipment	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Total	17.6	10.9	9.1	8.8	8.8	8.8	8.8
Cooperative R&D Agreements							
Operating expense	1.1	1.2	0.7	0.6	0.6	0.6	0.6
Total DOE Programs							
Operating expense	448.0	458.3	561.4	561.0	559.5	561.0	561.0
Capital equipment	15.2	7.0	26.9	34.7	22.1	19.7	19.7
General Plant Equipment (GPE)	3.3	4.3	7.1	7.1	7.1	7.1	7.1
Construction	8.8	6.3	6.8	9.0	1.6	0.0	0.0
Proposed construction	0.0	1.6	10.3	59.0	12.1	3.1	3.1
Total	475.3	477.5	612.5	670.8	602.4	590.9	590.9
Work for others							
Nuclear Regulatory Commission							
Operating expense	13.7	14.2	13.0	13.0	13.0	13.0	13.0
Capital equipment	0.8	0.0	0.0	0.0	0.0	0.0	0.0
Total	14.5	14.2	13.0	13.0	13.0	13.0	13.0
Department of Defense							
Operating expense	13.3	22.5	24.6	24.8	24.8	24.8	24.8
Capital equipment	1.4	0.7	0.0	0.0	0.0	0.0	0.0
Total	14.7	23.2	24.6	24.8	24.8	24.8	24.8
National Aeronautics and Space Administration							
Operating expense	3.1	2.6	3.3	3.7	3.7	3.7	3.7
Department of Health and Human Services							
Operating expense	4.7	2.1	3.8	3.6	3.6	3.6	3.6

Table 7.3
(continued)

	1996	1997	1998	1999	2000	2001	2002
Environmental Protection Agency							
Operating expense	2.5	1.4	2.4	2.6	2.6	2.6	2.6
National Science Foundation							
Operating expense	0.0	1.2	0.0	0.0	0.0	0.0	0.0
Federal Emergency Management Agency							
Operating expense	1.5	1.2	1.4	1.4	1.4	1.4	1.4
Capital equipment	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Total	1.5	1.3	1.5	1.5	1.5	1.5	1.5
Department of Transportation							
Operating expense	8.3	8.8	9.2	6.9	6.9	6.9	6.9
Capital equipment	0.2	0.3	0.3	0.3	0.3	0.3	0.3
Total	8.5	9.1	9.5	7.2	7.2	7.2	7.2
Other Federal agencies							
Operating expense	2.3	7.0	10.3	12.2	12.2	12.2	12.2
Electric Power Research Institute							
Operating expense	1.8	1.0	1.1	1.0	1.0	1.0	1.0
Other nonfederal agencies							
Operating expense	13.0	13.1	13.3	12.1	12.1	12.1	12.1
Capital equipment	0.5	0.0	0.0	0.0	0.0	0.0	0.0
Total	13.5	13.1	13.3	12.1	12.1	12.1	12.1
Total Work for Others							
Operating expense	64.2	75.1	82.4	81.3	81.3	81.3	81.3
Capital equipment	2.9	1.1	0.4	0.4	0.4	0.4	0.4
Total	67.1	76.2	82.8	81.7	81.7	81.7	81.7
Total Laboratory							
Operating expense	512.2	533.4	643.8	642.3	640.8	642.3	642.3
Capital equipment	18.1	8.1	27.3	35.1	22.5	20.1	20.1
General Plant Equipment (GPE)	3.3	4.3	7.1	7.1	7.1	7.1	7.1
Construction	8.8	6.3	6.8	9.0	1.6	0.0	0.0
Proposed construction	0.0	1.6	10.3	59.0	12.1	3.1	3.1
Total	542.4	553.7	695.3	752.5	684.1	672.6	672.6

Table 7.4

Personnel by assistant secretarial level office by fiscal year

[Full-time equivalent (FTE) employees]

	1996	1997	1998	1999	2000	2001	2002
Office of Energy Research							
Technical personnel	518.9	559.5	664.4	664.9	664.9	664.9	664.9
Other direct personnel	143.8	75.2	139.4	159.4	159.4	159.4	159.4
Total direct personnel	662.7	634.7	803.8	824.3	824.3	824.3	824.3
Office of Energy Efficiency and Renewable Energy							
Technical personnel	178.9	232.4	230.1	229.4	229.4	229.4	229.4
Other direct personnel	54.6	15.7	15.0	14.9	14.9	14.9	14.9
Total direct personnel	233.5	248.1	245.1	244.3	244.3	244.3	244.3
Office of Nuclear Energy, Science and Technology							
Technical personnel	31.9	55.3	51.0	53.8	54.6	54.6	54.6
Other direct personnel	19.5	29.9	29.9	29.9	29.9	29.9	29.9
Total direct personnel	51.4	85.2	80.9	83.7	84.5	84.5	84.5
Office of Fossil Energy							
Technical personnel	18.2	22.5	19.1	17.6	18.6	18.6	18.6
Other direct personnel	3.3	1.6	1.0	1.2	1.2	1.2	1.2
Total direct personnel	21.5	24.1	20.1	18.8	19.8	19.8	19.8
Energy Information Administration							
Technical personnel	0.5	0.5	0.4	0.4	0.4	0.4	0.4
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	0.5	0.5	0.4	0.4	0.4	0.4	0.4
Office of Defense Programs							
Technical personnel	35.3	46.3	54.1	48.5	48.5	48.5	48.5
Other direct personnel	11.6	21.9	27.2	27.4	27.4	27.4	27.4
Total direct personnel	46.9	68.2	81.3	75.9	75.9	75.9	75.9
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	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	0.1	0.0	0.1	0.1	0.1	0.1	0.1
Office of Fissile Materials Disposition							
Technical personnel	15.0	30.3	31.0	30.3	25.0	29.0	29.0
Other direct personnel	4.9	7.3	7.3	7.3	7.3	7.3	7.3
Total direct personnel	19.9	37.6	38.3	37.6	31.0	36.3	36.3
Office of Civilian Radioactive Waste Management							
Technical personnel	0.3	0.3	0.5	0.7	0.7	0.7	0.7
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	0.3	0.3	0.5	0.7	0.7	0.7	0.7
Office of Environment, Safety, and Health							
Technical personnel	22.0	41.8	32.9	31.6	31.6	31.6	31.6
Other direct personnel	4.7	4.1	2.7	1.9	1.9	1.9	1.9
Total direct personnel	26.7	45.9	35.6	33.5	33.5	33.5	33.5

Table 7.4
(continued)

	1996	1997	1998	1999	2000	2001	2002
Office of Policy, Planning and Program Evaluation							
Technical personnel	2.1	5.0	2.1	2.3	2.3	2.3	2.3
Other direct personnel	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	2.3	5.0	2.1	2.3	2.3	2.3	2.3
Federal Energy Regulatory Commission							
Technical personnel	6.3	5.4	4.4	4.3	4.3	4.3	4.3
Other direct personnel	0.3	0.1	0.1	0.1	0.1	0.1	0.1
Total direct personnel	6.6	5.5	4.5	4.4	4.4	4.4	4.4
Office of Economic Impact and Diversity							
Technical personnel	0.6	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	1.0	0.0	0.0	0.0	0.0	0.0	0.0
DOE funding from Energy Systems central organizations							
Technical personnel	314.4	389.1	386.9	373.8	373.8	373.8	373.8
Other direct personnel	356.7	298.9	298.8	298.4	298.4	298.4	298.4
Total direct personnel	671.1	688.0	685.7	672.2	672.2	672.2	672.2
Subtotal DOE Programs							
Technical personnel	1144.5	1388.4	1477.0	1457.7	1454.2	1458.2	1458.2
Other direct personnel	600.0	454.7	521.4	540.5	539.2	540.5	540.5
Total direct personnel	1744.5	1843.1	1998.4	1998.2	1993.4	1998.7	1998.7
DOE Contractors and Operations Office							
Technical personnel	44.6	54.8	29.5	18.9	18.9	18.9	18.9
Other direct personnel	5.7	1.9	0.7	0.7	0.7	0.7	0.7
Total direct personnel	50.3	56.7	30.2	19.6	19.6	19.6	19.6
Cooperative R&D Agreements							
Technical personnel	5.7	4.3	1.1	1.1	1.1	1.1	1.1
Other direct personnel	0.2	0.2	0.2	0.0	0.0	0.0	0.0
Total direct personnel	5.9	4.5	1.3	1.1	1.1	1.1	1.1
Total DOE Programs							
Technical personnel	1194.8	1447.5	1507.6	1477.7	1474.2	1478.2	1478.2
Other direct personnel	605.9	456.8	522.3	541.2	539.9	541.2	541.2
Total direct personnel	1800.7	1904.3	2029.9	2018.9	2014.1	2019.4	2019.4
Work for others							
Nuclear Regulatory Commission							
Technical personnel	58.6	69.6	61.9	57.7	57.7	57.7	57.7
Other direct personnel	13.9	5.1	4.1	2.7	2.7	2.7	2.7
Total direct personnel	72.5	74.7	66.0	60.4	60.4	60.4	60.4
Department of Defense							
Technical personnel	78.4	92.4	92.2	86.1	86.1	86.1	86.1
Other direct personnel	10.6	6.1	4.0	1.7	1.7	1.7	1.7
Total direct personnel	89.0	98.5	96.2	87.8	87.8	87.8	87.8

Table 7.4
(continued)

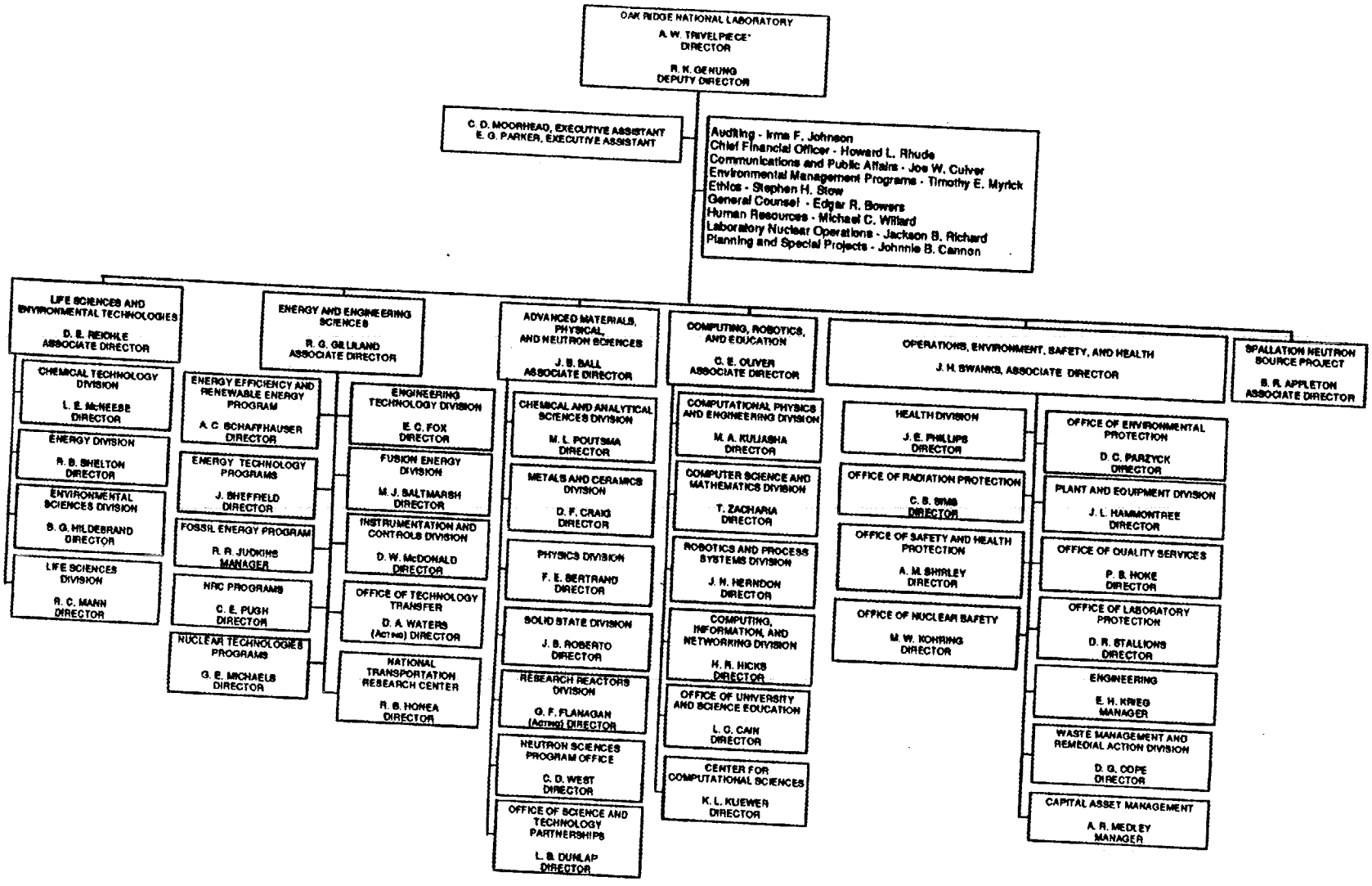
	1996	1997	1998	1999	2000	2001	2002
National Aeronautics and Space Administration							
Technical personnel	8.5	9.1	11.5	11.8	11.8	11.8	11.8
Other direct personnel	0.7	0.6	0.6	0.6	0.6	0.6	0.6
Total direct personnel	9.2	9.7	12.1	12.4	12.4	12.4	12.4
Department of Health and Human Services							
Technical personnel	23.8	18.0	16.3	15.5	15.5	15.5	15.5
Other direct personnel	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	23.9	18.0	16.3	15.5	15.5	15.5	15.5
Environmental Protection Agency							
Technical personnel	15.5	21.1	13.5	12.6	12.6	12.6	12.6
Other direct personnel	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Total direct personnel	15.5	21.2	13.5	12.6	12.6	12.6	12.6
National Science Foundation							
Technical personnel	0.0	1.6	1.4	1.5	1.5	1.5	1.5
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	0.0	1.6	1.4	1.5	1.5	1.5	1.5
Federal Emergency Management Agency							
Technical personnel	5.0	7.9	4.5	3.7	3.7	3.7	3.7
Other direct personnel	0.0	1.2	0.9	0.9	0.9	0.9	0.9
Total direct personnel	5.0	9.1	5.4	4.6	4.6	4.6	4.6
Department of Transportation							
Technical personnel	43.0	51.4	36.0	29.1	29.1	29.1	29.1
Other direct personnel	2.0	5.4	2.1	1.9	1.9	1.9	1.9
Total direct personnel	45.0	56.8	38.1	31.0	31.0	31.0	31.0
Other Federal agencies							
Technical personnel	22.7	13.7	45.5	50.4	50.4	50.4	50.4
Other direct personnel	2.1	0.2	0.1	0.1	0.1	0.1	0.1
Total direct personnel	24.8	13.9	45.6	50.5	50.5	50.5	50.5
Electric Power Research Institute							
Technical personnel	6.2	5.4	4.6	3.7	3.7	3.7	3.7
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	6.2	5.4	4.6	3.7	3.7	3.7	3.7
Other nonfederal agencies							
Technical personnel	42.7	39.8	33.7	35.2	35.2	35.2	35.2
Other direct personnel	5.8	2.7	1.8	0.7	0.7	0.7	0.7
Total direct personnel	48.5	42.5	35.5	35.9	35.9	35.9	35.9
Total Work for Others							
Technical personnel	304.4	330.0	321.1	307.3	307.3	307.3	307.3
Other direct personnel	35.2	21.4	13.6	8.6	8.6	8.6	8.6
Total direct personnel	339.6	351.4	334.7	315.9	315.9	315.9	315.9
Total ORNL							
Technical personnel	1499.2	1777.5	1828.7	1785.0	1781.5	1785.5	1785.5
Other direct personnel	641.1	478.2	535.9	549.8	548.5	549.8	549.8
Total ORNL direct personnel	2140.3	2255.7	2364.6	2334.8	2330.0	2335.3	2335.3
Total ORNL indirect personnel	2185.0	2150.0	2100.0	2000.0	2000.0	1950.0	1950.0
Total ORNL personnel	4325.3	4405.7	4464.6	4334.8	4330.0	4285.3	4285.3

Appendix • Abbreviations

AA	affirmative action
AEOD	NRC Office for Analysis and Evaluation of Operational Data
AMCL	Advanced Materials Characterization Laboratory
AMS	Applied Mathematical Sciences
AMTEX	American Textile Partnership
ANL	Argonne National Laboratory
APT	accelerator production of tritium
ATM	asynchronous transfer mode
ATR	Advanced Test Reactor
B&W	Babcock and Wilcox
BA	budget authority
BER	Biological and Environmental Research
BES	Basic Energy Sciences
BESAC	Basic Energy Sciences Advisory Committee
BNL	Brookhaven National Laboratory
BTC	Buildings Technology Center
CANDU	Canadian deuterium-uranium reactor
CCS	Center for Computational Sciences
CDR	conceptual design report
CERN	European Laboratory for Particle Physics (formerly Conseil Européen pour la Recherche Nucléaire)
CESAR	Center for Engineering Systems Advanced Research
CFC	chlorofluorocarbon
CGES	Center for Global Environmental Studies
CM	countermine
CME	Collaborative Management Environment
COE	Common Operating Environment
CRADA	cooperative research and development agreement
CSCP	Center for Separations and Chemical Processing
CTRC	Collaborative Technologies Research Center
D&D	decontamination and decommissioning
DARPA	Defense Advanced Research Projects Agency
DNA	deoxyribonucleic acid
DNFSB	Defense Nuclear Facilities Safety Board
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOE-DP	U.S. Department of Energy, Office of Defense Programs
DOE-EE	U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy
DOE-EH	U.S. Department of Energy, Office of Environment, Safety, and Health
DOE-EM	U.S. Department of Energy, Office of Environmental Management
DOE-ER	U.S. Department of Energy, Office of Energy Research
DOE-FE	U.S. Department of Energy, Office of Fossil Energy
DOE-HQ	U.S. Department of Energy, Headquarters

DOE-NE	U.S. Department of Energy, Office of Nuclear Energy, Science and Technology
DOE-ORO	U.S. Department of Energy, Oak Ridge Operations Office
EE/RE	Energy Efficiency and Renewable Energy
EEO	equal employment opportunity
EEO/AA	equal employment opportunity/affirmative action
EIA	Energy Information Administration
EMEF	Environmental Management and Enrichment Facilities
EOSDIS	Earth Observing System Data and Information System
EPA	U.S. Environmental Protection Agency
ER-LTR	Energy Research Laboratory Technology Research Program
ES&H	environment, safety, and health
ESH&Q	environment, safety, health, and quality
FACE	free-air carbon dioxide enrichment
FDA	Food and Drug Administration
FERC	Federal Energy Regulatory Commission
FFA	Federal Facilities Agreement
FY	fiscal year
HFIR	High Flux Isotope Reactor
HR	human resources
HRIBF	Holifield Radioactive Ion Beam Facility
HTML	High Temperature Materials Laboratory
I/O	input/output
IMP	Infrastructure Management Plan
IRM	information resource management
ISM	integrated safety management
ISOL	isotope separator on-line
LANL	Los Alamos National Laboratory
LBNL	Ernest Orlando Lawrence Berkeley National Laboratory
LCFG	Laboratory for Comparative and Functional Genomics
LDRD	Laboratory Directed Research and Development
linac	linear accelerator
LLLW	low-level liquid waste
LLNL	Lawrence Livermore National Laboratory
LMER	Lockheed Martin Energy Research Corporation
LMES	Lockheed Martin Energy Systems, Inc.
LWR	light-water reactor
M&I	management and integration
M&O	management and operation
MEI	minority educational institution
MOU	memorandum of understanding
MOX	mixed-oxide
MSRE	Molten Salt Reactor Experiment
N&S	necessary and sufficient
NAA	neutron activation analysis
NASA	National Aeronautics and Space Administration
NEPA	National Environmental Policy Act
NIH	National Institutes of Health
NMSS	NRC Office of Nuclear Material Safety and Safeguards
NOAA	National Oceanic and Atmospheric Administration
NRC	Nuclear Regulatory Commission
NRR	NRC Office of Nuclear Reactor Regulation
NSAC	Nuclear Science Advisory Committee
NSF	National Science Foundation
NSSA	National Safe Skies Alliance

NTRC	National Transportation Research Center
OBER	DOE Office of Biological and Environmental Research
OCTR	DOE Office of Computational and Technology Research
OES&H	Operations, Environment, Safety, and Health
ORCMT	Oak Ridge Centers for Manufacturing Technology
ORELA	Oak Ridge Electron Linear Accelerator
ORISE	Oak Ridge Institute for Science and Education
ORNL	Oak Ridge National Laboratory
OUSE	Office of University and Science Education
P2	Pollution Prevention
PHENIX	Pioneering High-Energy Nuclear Interaction Experiment
PNGV	Partnership for a New Generation of Vehicles
QA	quality assurance
QCD	quantum chromodynamics
R&D	research and development
REDC	Radiochemical Engineering Development Center
RES	NRC Office of Nuclear Regulatory Research
rf	radio frequency
RIB	radioactive ion beam
RNA	ribonucleic acid
RPV	reactor pressure vessel
SHaRE	Shared Research Equipment
SMACRC	Surface Modification and Characterization Research Center
SNL	Sandia National Laboratories
SNS	Spallation Neutron Source
teraflops	trillions of floating point operations per second
TVA	Tennessee Valley Authority
UT	The University of Tennessee
UXO	unexploded ordnance
VPP	Voluntary Protection Program
WMRAD	Waste Management and Remedial Action Division



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EFFECTIVE DATE:	MARCH 2, 1998

LOCKHEED MARTIN ENERGY RESEARCH CORPORATION