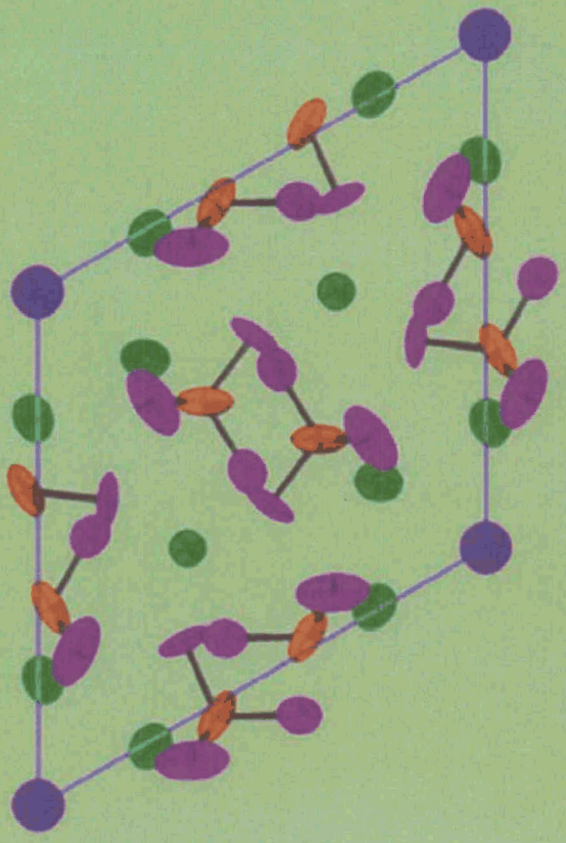
OAK RIDGE
NATIONAL LABORATORY

MANAGED BY UT-BATTELLE
FOR THE DEPARTMENT OF ENERGY

ORNL/PPA-2001/2

Oak Ridge National Laboratory
Institutional Plan
FY 2002–FY 2006



UT-BATTELLE

ORNL-27 (4-00)

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On the cover: "Seeing" the atomic arrangement of carbonate apatite, a major component of teeth and bones, through the use of neutron scattering could lead to the development of synthetic materials that are similar in structure.

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ORNL/PPA-2001/2

Oak Ridge National Laboratory Institutional Plan

FY 2002–FY 2006

December 2001

Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831-6285
managed by
UT-Battelle LLC
for the
U.S. Department of Energy
under contract DE-AC05-00OR22725

Contents

1 • Laboratory Director's Statement

UT-Battelle, LLC, a partnership between the University of Tennessee (UT) and Battelle, has made significant progress during its first year at Oak Ridge National Laboratory (ORNL). We have developed a Laboratory Agenda that captures the principal elements through which we will deliver on our commitment to simultaneous excellence in science and technology; Laboratory operations and environment, safety, and health (ES&H); and community service. In implementing this agenda, we have moved aggressively to sustain and enhance ORNL's capabilities for science and technology. Six major Laboratory initiatives are positioning us to deliver advances that support the missions of the Department of Energy (DOE) in science, energy, environmental quality, and national nuclear security. We have also launched major efforts to modernize the Laboratory's facilities, to enhance our operational discipline, and to maximize our research effectiveness. In addition, we are reaching out to the community through activities in education, technology transfer, and economic development. These activities, described in detail in this Institutional Plan, are summarized below.

Much more remains to be done. We look forward to working closely with DOE, both at Headquarters and in the Oak Ridge Operations Office, as we strive to deliver on our commitment to simultaneous excellence. We are working with other prime contractors across the Oak Ridge Reservation to develop partnerships that produce maximum synergy at this complex site. We are also working with other national laboratories to increase the value of the science and technology delivered to DOE and other agencies. Our emphasis on partnerships extends to our relationships with our six "core" universities and Oak Ridge Associated Universities (ORAU), area schools and colleges, local and regional economic development agencies, and the state of Tennessee. These partnerships will be a key tool in positioning ORNL for the future, as documented in this Institutional Plan.

Excellence in Science and Technology

The scientific and technological capabilities of any national laboratory are the essence of its character. At ORNL, we have an extraordinarily broad and deep suite of skills that serves all of DOE's missions. We support these missions through continued excellence in program execution for our DOE sponsors; through application of our capabilities to the needs of other customers, leading to focused, mission-driven growth; and through major initiatives that sustain and enhance the Laboratory's distinctive capabilities.

These initiatives build on ORNL's rich history and address well-defined areas tied directly to DOE's Strategic Plan, research and development (R&D) portfolios, and science and technology roadmaps. We are focusing on six major areas.

- **Neutron sciences.** New and upgraded facilities, expanding research programs, and scientific contributions from Laboratory staff and partners promise to make ORNL the world's premier research center for neutron sciences in the near future. Excellent progress has been made on the Spallation Neutron Source (SNS), scheduled for completion in FY 2006, and on the upgrading of the High Flux Isotope Reactor (HFIR). Completion of these tasks will provide some of the world's best tools for neutron scattering, thus advancing DOE missions in broad areas of materials science, chemistry, biology, and engineering. The Joint Institute for Neutron Sciences, to be housed in a new facility funded by the state of Tennessee, will also enhance the development of the neutron sciences through partnerships, educational activities, and user support infrastructure.
- **Complex biological systems.** Our Complex Biological Systems Initiative takes advantage of revolutionary advances in molecular biology, bioanalytical technologies, and computational science,

focusing these new capabilities and the information derived from comparative genomics on understanding the complex interactions, pathways, balances, and control mechanisms of biological systems. We will apply our expertise and facilities to the challenges of observing and understanding the functioning of complex biological systems, exploring areas of critical interest to DOE such as the challenges posed by the Genomes to Life program, bioremediation, carbon sequestration, and renewable and alternative energy sources. This initiative will benefit from our plans to develop a new Center for Systems Biology at ORNL. The anchor facility for this center is the Laboratory for Comparative and Functional Genomics, which will provide a new home for ORNL's mouse colony. Design work for this building is under way, with completion expected in early FY 2003. Also planned is the construction of a facility, funded by the state of Tennessee, to house the Joint Institute for Biological Sciences.

- **High-performance computing.** Our Terascale Computing and Simulation Science Initiative supports DOE's needs in unclassified high-performance computing, networking, and simulation science. ORNL maintains one of the most powerful unclassified computing centers in the world, enabling researchers to solve problems of unprecedented complexity, leading to new scientific discoveries. This initiative involves continued development, integration, and application of advances in computer science, high-performance algorithms, software tools, and computational capabilities to solve challenging scientific and engineering problems. It also includes the construction of two new facilities: a privately funded Computational Sciences Building and a building funded by the state of Tennessee to house the Joint Institute for Computational Sciences.
- **Energy and environmental sciences.** Our Energy and Environmental Systems of the Future (E^2SF) Initiative addresses the broad challenge, put forward in the Department's mission statement, of fostering "a secure and reliable energy system that is environmentally and economically sustainable." The development of this system requires not only advances in science and technology but also new capabilities for evaluating and assessing the economic and environmental consequences of new energy technologies and energy policy decisions. We are developing an approach that we call "E^3" to reflect the necessary integration of energy, economics, and environment. This initiative links ORNL's extensive capabilities for R&D on energy production, distribution, and use with our research on the effects of energy technologies and decisions on the environment and society. We will build on our broad programs in energy science and technology, global climate science and carbon management, and analytical sciences and engineering and expand our expertise in integrated assessment, working with national and international research partners to accelerate the understanding of key energy issues.
- **Advanced materials.** Our Advanced Materials Initiative is designed to sustain ORNL's position as a world-class materials R&D laboratory supporting DOE missions. A key aspect of this initiative is the development of a program, supported by the focused investment of Laboratory Directed R&D (LDRD) funds, in nanoscale science, engineering, and technology. This program supports DOE's continuing efforts to advance the fundamental understanding of nanoscale phenomena through experiment, theory, and simulation. The Advanced Materials Initiative comprises the development of new methods for predicting these phenomena and for extending the ability to design, synthesize, and characterize materials at the atomic level, leading to new and enhanced functionality. The Center for Nanophase Materials Sciences, to be constructed at the SNS site, is the centerpiece of this initiative. Also included is the construction of a new Advanced Materials Characterization Laboratory to provide the high-quality environment needed for the sophisticated characterization equipment that is essential to the next generation of materials R&D.
- **National security.** In addition to work that directly supports the National Nuclear Security Administration, ORNL is engaged in R&D that can lead to advances in scientific understanding and technology that address the security-related needs of other federal, state, and local agencies. Our National Security Initiative is designed to maintain and expand the Laboratory's position as a key resource in the development of national security and public safety technologies and expertise for federal, state, and local governments. It takes advantage of our proximity to the Y-12 National

Security Complex, linking capabilities across ORNL and the Y-12 Advanced Technologies organization to address such areas as emerging nontraditional threats (e.g., asymmetric warfare), weapons of mass destruction or mass effects, commercial and military logistics, public safety, and emergency planning and management.

Excellence in Laboratory Operations and ES&H

We are proceeding with three initiatives to ensure the safe, secure, and cost-efficient operation of ORNL. Modernizing the Laboratory's infrastructure is essential to its future. We simply cannot continue to conduct cutting-edge research in World War II–era buildings. The poor condition of the physical plant at ORNL is a leading ES&H concern, complicates the approach to access control, and adds considerably to overhead costs in terms of energy consumption, maintenance, etc. The creation of a new "research campus" builds on support from DOE programs, the commitment by the state of Tennessee to build four new buildings at ORNL, and the commitment of UT-Battelle to enable private-sector development of three new facilities during the planning period.

In September 2000, DOE announced plans to invest $125 million in the new research campus. In combination with $26 million in state funds and $50 million to $60 million from private-sector investors, this investment will support the construction of 14 major facilities and the renovation of several others over the next 5 years. We expect to begin construction of the three privately funded facilities in early FY 2002. When construction and renovation are completed in 2006, ORNL will have replaced 1.8 million square feet of aging and outdated space with about 600,000 square feet of modern, energy-efficient buildings that will support cutting-edge research programs, enhance our ability to work with scientists and engineers from other institutions, improve safety, and reduce the cost of operations, thus contributing to our second major operational initiative: maximizing research effectiveness.

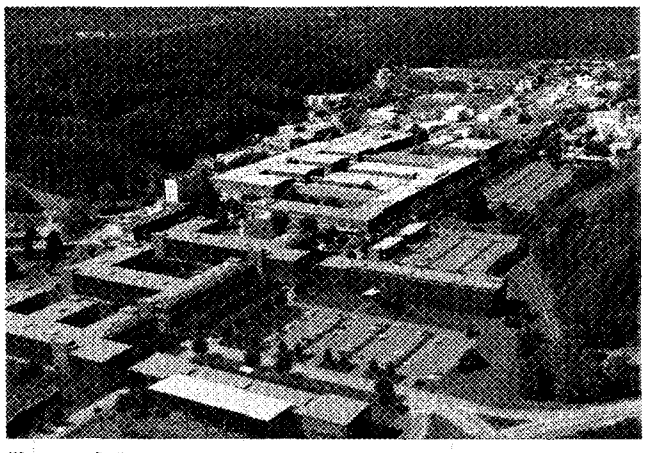


Figure 1.1
An artist's conception of ORNL's new campus.

We are committed to providing maximum R&D per dollar spent at ORNL and are working to drive down the cost of doing business at ORNL, with a goal of reducing indirect costs by $30 million by the end of FY 2003. Despite some notable challenges in this area, including increased utility costs, we are making good progress. Workforce restructuring programs have reduced the number of staff positions by almost 400. At the same time, we are working to attract and retain employees with critical skills for mission execution. A new performance management and compensation program is being implemented. Salaries for ORNL employees have been far below market value for several years. We have made good progress in closing this gap. We have conducted a "quality of work life" survey and are analyzing the results. A review of employee benefits, identified as a priority issue, is under way. We are also taking action to streamline our business operations.

Enhancing the discipline of our operations is the third initiative that we are undertaking in order to deliver on our commitment to excellence in operations and ES&H. We have implemented a chemical reuse program and begun a shift to a landlord/tenant model for facility operations, and work is under way to deploy a Standards-Based Management System. We are setting in place the necessary systems and management leadership to enhance overall ES&H and operational performance. We are also stressing the importance of rigorous self-assessment to drive continuous improvement in all that we do.

Excellence in Community Service

We are demonstrating our commitment to excellence in community service by contributing to the community as a good neighbor, a resource for knowledge and technology, and a valued partner in education and economic development. UT-Battelle has provided funds in excess of $1.2 million for community initiatives and educational, civic, and economic development activities. Community involvement is expected from members of the UT-Battelle Leadership Team and encouraged for all employees. The formation of "Team UT-Battelle" supports employee participation in community projects such as the construction of Habitat for Humanity houses. We have established, in partnership with Technology 2020, a regional Center for Entrepreneurial Growth. We are also fostering local economic growth by establishing innovative research partnerships and increasing our technical assistance to businesses and industry. Since April 2000, 24 new companies based on ORNL knowledge and technology have been established. We are expanding our partnerships with universities, with a focus on the six UT-Battelle "core" universities (Virginia, Virginia Tech, Duke, North Carolina State, Georgia Tech, and Florida State), to broaden access to ORNL's resources. UT-Battelle is supporting science education by funding the purchase of new equipment for science laboratories in area schools and increasing opportunities for Tennessee teachers at the Academy for Teachers of Science and Mathematics at UT. We are also working with the community to secure the future of the American Museum of Science and Energy. A long-term financial stability plan was presented to the City of Oak Ridge in November 2000. The city's response to the plan, issued in March 2001, has been favorably reviewed by DOE's Oak Ridge Operations Office, and a decision by the City Council is expected in December 2001. UT-Battelle has agreed to help set up an endowment fund to ensure continued operation of the facility.

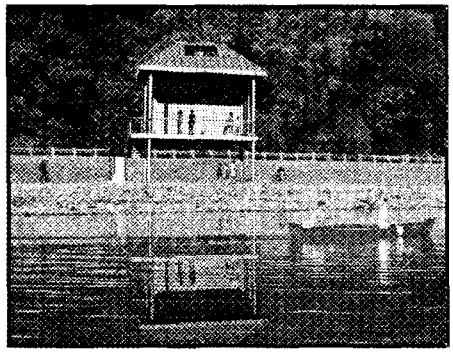


Figure 1.2
A designer's conception of a new rowing tower on Melton Hill Lake, funded in part by UT-Battelle.

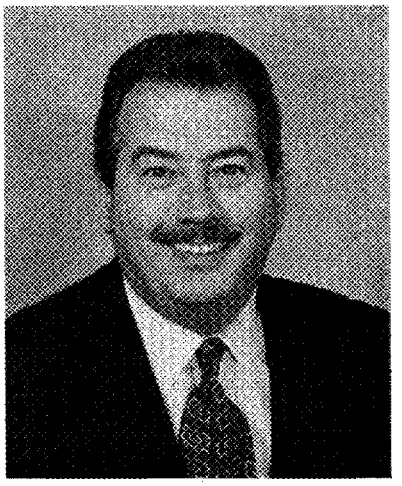
Partnerships

Partnerships are both necessary and desirable for delivering on our commitments in science and technology, operations and ES&H, and community service. The strong partnership between ORNL and DOE, both at Headquarters and at the local level, is a key to effective Laboratory operations. Our relationship with the state of Tennessee holds the potential for creating a fundamentally new federal-state partnership based around national laboratories. Through participation in the Tennessee Technology Development Corporation, especially as a resource for the Technopreneurial Leadership Center, we are contributing to the growth of Tennessee's technology businesses. The partnerships with our six "core" universities and ORAU are raising national laboratory–university relations to a new level. With ORAU, we have also created a summer research participation program for faculty from Historically Black Colleges and Universities and other Minority Educational Institutions. Five Tennessee universities have created a coalition, funded by the National Science Foundation's Partnerships for Innovation program, to foster innovation in the biotechnology industry in Tennessee, drawing on ORNL science and technology. Their efforts will help to translate the knowledge created at the Laboratory into new products, businesses, and services that enrich the local economy. Finally, we are building partnerships with other prime contractors across the Oak Ridge Reservation to enhance safety and achieve maximum synergy at this complex site.

Outlook for the Planning Period

We look forward to delivering on UT-Battelle's commitment to simultaneous excellence in science and technology, Laboratory operations and ES&H, and community service as we support DOE in carrying out its missions. Our aim is to sustain and extend the Laboratory's status as a dynamic and efficient institution, comprising both the cutting-edge facilities and the skilled and talented staff that are essential to carrying out our mission assignments.

We are certain to face challenges, both expected and unexpected, in delivering on our commitment to simultaneous excellence. We believe, however, that we are well equipped to meet these challenges, and we look forward to the opportunities that lie ahead.



William J. Madia
Director,
Oak Ridge National Laboratory

2 • Mission and Roles

2.1 • Mission Statement

The Oak Ridge National Laboratory (ORNL) is a multiprogram science, technology, and energy laboratory with distinctive capabilities in materials science and engineering, neutron science and technology, energy production and end-use technologies, mammalian genetics, environmental science, and scientific computing. In support of the missions of the U.S. Department of Energy (DOE), ORNL 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.

ORNL is managed for DOE by UT-Battelle LLC, a partnership between the University of Tennessee (UT) and Battelle.

2.2 • Mission Roles

As a multiprogram national laboratory, ORNL carries out R&D in support of all four of DOE's major missions: science, energy resources, environmental quality, and national nuclear security. As described in the *Strategic Laboratory Missions Plan—Phase I* (Laboratory Operations Board, U.S. Department of Energy, July 1996), the Laboratory plays a principal role in fundamental science and energy resources and has a specialized participating role in environmental quality and national nuclear security.

2.2.1 • Key R&D Activities

2.2.1.1 • Science

ORNL's R&D in science supports the delivery of the scientific advances and technical innovations that enable DOE to carry out its missions. The Laboratory conducts R&D for DOE in basic energy sciences, biological and environmental research, fusion energy sciences, advanced scientific computing research, and nuclear physics. Activities span the following fields:

- Materials science and engineering, with emphasis on development of ceramics and composites, metals and alloys, carbon-based materials, surfaces and thin films, polymers, and high-temperature superconductors; nanoscale science and engineering; and new techniques for materials synthesis, processing, and characterization
- Neutron science, with strengths in neutron scattering, isotope production, and design and operation of accelerator-based and reactor-based neutron sources
- Life sciences, with emphasis on functional genomics and proteomics, biotechnology, bioengineering, computational biology, and bioinformatics
- High-performance computing, with emphasis on computer and computational science, distributed computing, networking, and intelligent systems
- Environmental sciences, spanning ecosystem research and global change science, environmental processes science and technology, microbial ecology and genomics, plant sciences and genomics, ecological management science and technology, renewable resources R&D, and environmental data systems

- Separations and analytical chemistry, chemical sciences, and chemical engineering technology, with activities in separations science, hydrothermal solution chemistry and geochemistry, actinide science and radioactive materials characterization, isotope separations, computational chemistry and chemical engineering, integrated chemical and bioanalytical instrumentation, miniaturization of chemical reactions and separations, mass spectrometry, environmental monitoring and technology, materials chemistry, fundamental chemistry of energy production and use, and interface and surface science
- Fusion science and technology, spanning plasma theory, magnetic confinement experiments, plasma heating and fueling, atomic physics, and materials development
- Studies of the fundamental properties of matter at the atomic, nuclear, and subnuclear level, focusing on (1) nuclear structure physics and nuclear astrophysics with radioactive ion beams; (2) relativistic heavy-ion beam physics, aimed at the creation and characterization of the quark-gluon plasma; and (3) atomic, molecular, and optical physics
- Instrumentation and measurement science and technology
- Robotics and intelligent machines
- Social sciences, providing support for planning and policy decisions related to major energy and environmental issues

DOE's Office of Science (DOE-SC) is the largest single sponsor of R&D at ORNL. The Laboratory carries out work for the Offices of Basic Energy Sciences, Biological and Environmental Research, Advanced Scientific Computing Research, Fusion Energy Sciences, and High Energy and Nuclear Physics. Other sponsors of R&D in science include the National Aeronautics and Space Administration, the U.S. Department of Defense, the U.S. Department of Health and Human Services, and the National Science Foundation.

2.2.1.2 • Energy Resources

ORNL's in-house energy programs, the largest and most broadly based among the DOE national laboratories, span basic and applied research, technology development, technical assistance, and management of energy-related information. These programs link the physical, engineering, environmental, economic, and social sciences to provide not only new science and technology but also 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. Key focus areas are the following:

- Energy-efficient technologies for buildings, industrial, transportation, and utility end-use
- Bioenergy, with a focus on sustainable biomass feedstock and conversion technologies
- Distributed energy resources, emphasizing integrated systems and utility reliability
- Carbon sequestration R&D
- Fossil energy, emphasizing applied materials, fuel cells, and efficient turbine systems
- Nuclear technology and safety

Most of this work is sponsored by DOE's Offices of Energy Efficiency and Renewable Energy, Fossil Energy, and Nuclear Energy, Science and Technology. Other sponsors include the U.S. Department of Transportation, the U.S. Department of Defense, the Nuclear Regulatory Commission, and the Environmental Protection Agency.

2.2.1.3 • Environmental Quality

ORNL supports the cleanup of DOE's environmental legacy through the integration of capabilities in analytical chemistry, biochemical engineering, bioremediation, biotechnology, chemical separations, earth and ecological sciences, environmental chemistry and engineering, geological sciences, instrumentation and measurement science and technology, and robotics and intelligent machines. Key R&D activities include the following:

- Environmental management science
- Environmental technology development
- Life-cycle analysis and health and environmental risk assessment

DOE's Office of Environmental Management (DOE-EM) provides funding to ORNL for basic and applied research, development, demonstration, and technical support to address environmental management problems, principally at DOE sites, with increasing emphasis on technology transfer. Work that supports waste management and remedial action projects at DOE's Oak Ridge, Paducah (Kentucky), and Portsmouth (Ohio) sites is coordinated with Bechtel Jacobs Company LLC, which manages DOE's Oak Ridge environmental management program under a management and integration contract. Much of the R&D, however, serves other DOE sites. DOE's Environmental Management Science Program, a collaborative initiative of DOE-EM and DOE-SC, sponsors basic research to address long-term technical issues and solve challenging problems presented by DOE's environmental legacy. Fundamental research on the bioremediation of metal and radionuclide contaminants is supported by DOE-SC, and ORNL manages the Field Research Center of the DOE-SC Natural and Accelerated Bioremediation Program, a focal point for field-scale research on bioremediation of metals and radionuclides. ORNL also performs work for the Environmental Protection Agency.

2.2.1.4 • National Nuclear Security

ORNL contributes to DOE's mission of reducing the global nuclear danger through national nuclear security, nuclear safety, and nonproliferation activities through efforts in three areas:

- Management and disposition of weapons-related nuclear material
- Promoting nonproliferation and international nuclear safety, with a growing emphasis on reducing the threat from biological, chemical, and nuclear agents
- High-performance computing

Funding from the Office of the Deputy Administrator for Defense Programs (DOE-DP) in DOE's National Nuclear Security Administration (NNSA) supports nuclear weapons R&D, high-performance computing, and facility transition.

The NNSA Office of the Deputy Administrator for Defense Nuclear Nonproliferation (DOE-NN) supports R&D activities and technical assessments related to national security requirements. Much of this work is performed through partnerships with the Y-12 National Security Complex. The DOE-NN Office of Fissile Materials Disposition supports the development of nuclear-based technologies for fissioning surplus plutonium in power reactors and efforts to dispose of surplus ^{233}U.

Other sponsors of work related to national security include the DOE Offices of Counterintelligence, Intelligence, and Security and Emergency Operations; the U.S. Department of Defense; the U.S. Department of Justice; the Federal Aviation Administration; the Federal Emergency Management Agency; and other government agencies with a focus on intelligence collection and analysis.

2.2.2 • Other Activities

ORNL produces isotopes for use in industry, medicine, and research; provides technical leadership and field management to DOE programs; operates information analysis centers; serves as a national repository for ^{233}U; and performs other tasks, frequently on an ad hoc basis, for DOE organizations.

ORNL transfers the knowledge and technology that are the products of its R&D to the private sector through a variety of mechanisms, including partnerships, personnel exchanges, and licensing of intellectual property.

ORNL actively supports the education of the next generation of scientists, engineers, technicians, and educators through a variety of programs for students and faculty at all academic levels.

2.2.3 • Major Facilities

An important part of DOE's science mission is conceiving, constructing, and operating large-scale, complex facilities for R&D. ORNL is home to 18 designated national user facilities (more than any other national laboratory) that are available to laboratory, industrial, and academic users. It also operates a number of other facilities that are used in executing DOE missions. Major facilities are listed in Table 2.1.

Table 2.1
Major facilities at ORNL

Designated user facilities
Advanced Propulsion Technology Center
Bioprocessing Research Facility
Buildings Technology Center
Californium User Facility for Neutron Science
Center for Structural Molecular Biology
High Flux Isotope Reactor: Neutron Scattering Research Facilities
High Temperature Materials Laboratory
Holifield Radioactive Ion Beam Facility
Metals Processing Laboratory User Center
Metrology R&D Laboratory
Mouse Genetics Research Facility
National Transportation Research Center
Oak Ridge Electron Linear Accelerator
Oak Ridge National Environmental Research Park
Physical Properties Research Facility
Power Electronics and Electric Machinery Research Center
Shared Research Equipment Collaborative Research Center
Surface Modification and Characterization Collaborative Research Center
Other key facilities
Center for Computational Sciences
Center for Engineering Science Advanced Research
Center for Separations and Chemical Processing
Ecological and Physical Sciences Study Center
Irradiated Fuels Examination Laboratory
Multicharged Ion Research Facility
Natural and Accelerated Bioremediation Research Program Field Research Center
Radiochemical Engineering Development Center
Radioisotope Development Facility
Robotics Technology Assessment Facility
Spallation Neutron Source

2.2.4 • Major Partnerships and Collaborations

ORNL uses partnerships as a means of conducting collaborative R&D and performing work for customers other than DOE; of transferring technology to industry and assisting in its commercialization; and of supporting the education of the next generation of scientists and engineers.

R&D partnerships and collaborations are described in detail in Sect. 6. Planned work for other sponsors, which helps ORNL to maintain the R&D expertise available to DOE and broadens the application of the Laboratory's strengths to mission-related needs, is described in Sect. 5.6, with detailed descriptions of ongoing work provided in the Supplemental Information appended to this report. Technology transfer and economic development activities are described in Sect. 8.1, and education partnerships are discussed in Sect. 8.2.

3 • Laboratory Strategic Plan

UT-Battelle's plan for the Oak Ridge National Laboratory (ORNL) is guided by a commitment to achieving simultaneous excellence in the areas of science and technology; Laboratory operations and environment, safety, and health (ES&H); and community service, as indicated in Fig. 3.1. The Laboratory Agenda provides a structured framework for the long-term initiatives, critical outcomes, and near-term actions through which UT-Battelle will deliver on this commitment.

Expectations and assumptions about the world in which the Laboratory operates are presented in Sect. 3.1, and the Laboratory Agenda is discussed in Sect. 3.2. Our major research initiatives are described in detail in Sect. 4, where we also show how they contribute to the missions of the Department of Energy (DOE). Section 5 provides descriptions of the ORNL research and development (R&D) programs that support DOE missions, and Sect. 6 discusses our use of R&D partnerships. Section 7 summarizes our strategy for maintaining and operating the facilities and carrying out the support functions required for mission accomplishment, and Sect. 8 outlines our plans for community service. Strategic issues are presented for DOE consideration in Sect. 9.

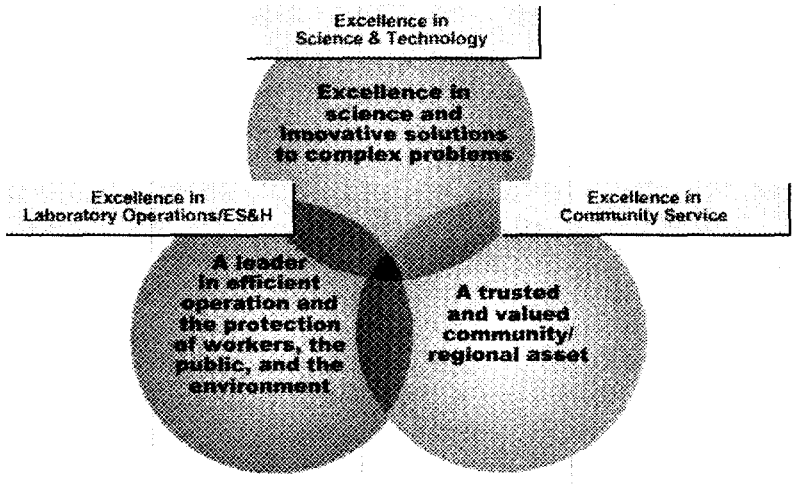


Figure 3.1
The UT-Battelle commitment to simultaneous excellence.

3.1 • Strategic View

We envision expanding opportunities in "science at the boundaries"—the linking of different disciplines to address scientific and technical challenges with far-reaching implications. For ORNL, many of these opportunities will be found in issues surrounding energy—its fundamental nature, its sources, its production and use, its effects on human health and the environment, and the economic impacts of energy technologies and policy decisions.

We expect that ORNL will remain a government-owned, contractor-operated multiprogram national laboratory, with DOE as its primary sponsor. In its work for DOE, ORNL will continue to play a principal role in science and energy resources and to apply specialized capabilities to support the Department's needs in environmental quality and national nuclear security. The integration of complementary capabilities distributed across DOE's national laboratory system, through traditional collaborative arrangements and increasingly through advanced "collaboratories" that link distant

resources and support remote experimentation, will be a key to the advances in science and technology needed to achieve DOE's strategic goals.

Work for other sponsors will continue to be a significant part of our portfolio. We will actively seek new opportunities to apply ORNL's expertise and capabilities to the needs of other federal agencies and other customers in both the public and the private sector as a means of increasing the transfer of knowledge and technologies to the marketplace, improving the utilization of facilities and expertise, maintaining specialized capabilities, and broadening the Laboratory's funding base.

Partnerships with universities, private industry, state and local governments, and international organizations will continue to strengthen and extend Laboratory programs while expanding access to qualified users of ORNL's resources and facilities. Collaborative relationships that extend across agencies and institutions will be a key to the efficient delivery of R&D that addresses emerging national priorities in such areas as computing and communications, environmental protection, health care, manufacturing, national safety and security, and transportation.

We will maintain our focus on continually improving ORNL's ability to operate safely, securely, and efficiently at reasonable cost while delivering on our mission assignments. Critical assets—including a diverse and talented staff, state-of-the-art research facilities, and specialized capabilities—will be protected and enhanced. Most of the Oak Ridge Reservation land area, which represents an irreplaceable resource, will continue to be retained by DOE to meet near-term and long-term programmatic needs. The Laboratory's Integrated Safety Management System will ensure that safety considerations are fully integrated into the planning and execution of all research and support activities. The performance-based contract between DOE and UT-Battelle provides explicit measures for assessing the quality of the Laboratory's work.

Concerns about the performance and productivity of the federal government, which gave rise to the Government Performance and Results Act of 1993 (GPRA), will continue. DOE's Strategic Plan and Strategic Management System, which respond to GPRA requirements, as well as the strategic plans of DOE programs, the R&D portfolios for each of DOE's business lines, and the roadmaps developed for critical technologies, will guide and direct our strategic planning.

The increasing prominence of policy issues with a significant science and technology component—such as the threats posed by weapons of mass destruction, the possible effects of human actions on the global climate, and rising demands for energy in developing nations—will sustain the growing recognition that science and technology can boost economic growth, strengthen national security, and improve human health and the environment. Despite support for R&D as a contributor to national well-being, however, discretionary resources for federally funded R&D are not expected to grow substantially, and competition for these scarce resources will remain intense.

Clearly, the availability and stability of funding for major initiatives and core programs will be the most important factor in our ability to carry out our Laboratory Agenda. Other external factors that will affect ORNL's future include the following:

- Explorations of the natural world at the level of the atom, the quantum, and the gene will produce dramatic advances in science and technology.
- Modeling and simulation will become increasingly important in many scientific fields, drawing on and driving advances in computational science and computing power.
- Growing evidence for changes in global climate as the result of human actions, coupled with increases in world population and energy demand, will create a major impetus for broadly based R&D programs to understand the effects of global climate change on ecosystems and society, increase energy efficiency, create new sources of clean energy, manage carbon emitted from the global energy system, and reduce greenhouse gas emissions.
- The national energy system is undergoing a significant transition in response to changes in regulatory frameworks, waste management requirements, alternative energy costs, and other factors. The transition to a deregulated electricity industry offers opportunities for increased deployment of renewable energy technologies, nuclear power, and other clean energy systems, but it also heightens

concerns about the cost, reliability, safety, and environmental impact of systems for the production, transmission, and distribution of energy.

- As technology becomes increasingly available to organizations or countries whose goals and interests conflict with those of the United States, this nation must constantly improve its capabilities to detect, degrade, defeat, and mitigate the impact of weapons of mass destruction or mass effects.
- The nation's increasing dependence on interconnected critical infrastructures (e.g., banking and finance, energy, telecommunications, transportation, water systems, and essential government services) will create a demand for new and better forms of protection against physical and cyber threats.
- In an increasingly technological society, lifelong learning about science, mathematics, engineering, and technology through formal and informal education will be essential.

3.2 • Laboratory Agenda

The Laboratory Agenda (see Fig. 3.2) is focused on the most significant activities that UT-Battelle must accomplish to deliver on its vision of simultaneous excellence in science and technology, Laboratory operations and ES&H, and community service. The Laboratory Agenda includes clear statements of the primary results that will be delivered to DOE over the next few years, as documented below.

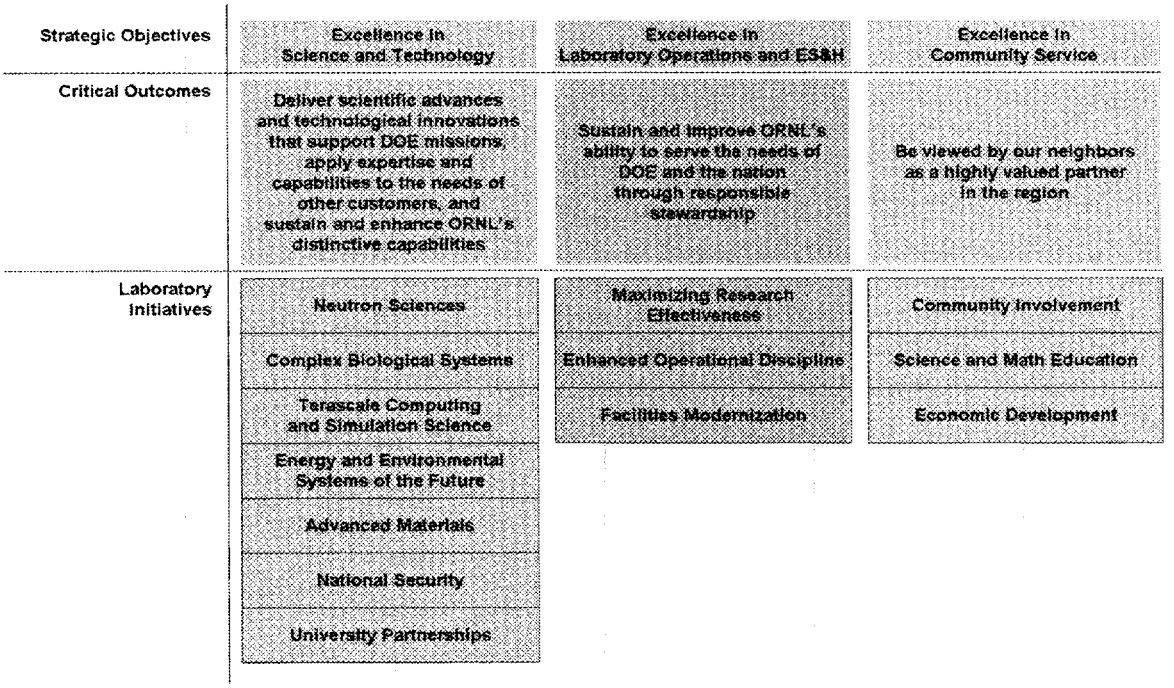


Figure 3.2
Major elements of ORNL's Laboratory Agenda.

Strategic Objective 1: Excellence in Science and Technology

To achieve excellence in science and technology, we will continue to deliver scientific advances and technological innovations in support of DOE's missions through diverse and extensive R&D programs that anticipate and respond to our sponsors' needs. In addition, we will pursue opportunities to apply our expertise and capabilities to the needs of other customers, leading to focused, mission-driven growth. Finally, we will prepare the Laboratory to address future national needs for science and technology through major initiatives that sustain and extend its distinctive capabilities. These initiatives represent the "critical few" areas that, because of their importance to the Laboratory, will receive special attention during the planning period.

1. Neutron Sciences. ORNL will become the world's foremost center for neutron sciences by enhancing its capabilities and applying them to deliver new insights into the nature, structure, and behavior of materials.

We are committed to the following actions.

- Deliver the Spallation Neutron Source (SNS) project on schedule and within budget.
- Upgrade the capabilities of the High Flux Isotope Reactor (HFIR).
- Develop innovative research programs that take advantage of the unique capabilities afforded by these facilities.
- Build a world-class user program that provides access to these capabilities.
- Construct a facility, funded by the state of Tennessee, for the Joint Institute for Neutron Sciences.

2. Complex Biological Systems. ORNL will be a center of excellence and a resource for understanding complex biological systems, from the molecular level to the level of the organism, and the interactions of organisms with the environment. Innovative means for observing and understanding the functioning of complex biological systems are developed and applied to meeting DOE's needs in systems biology, carbon management, renewable energy, and environmental quality.

We are committed to the following actions.

- Establish the Center for Systems Biology to consolidate the Laboratory's life and environmental sciences resources at the main ORNL site.
- Advance structural biology by combining ORNL's resources in neutron sciences, mass spectrometry, and computational biology through the Center for Structural Molecular Biology.
- Address critical issues in functional genomics and proteomics, using ORNL's mutant mouse resources and strengths in mutagenesis, phenotype screening, plant and microbial sciences, ecosystem genomics, computational tools, and analytical technologies.
- Integrate and extend ORNL's resources in computational biology and bioinformatics to advance the modeling of complex biological systems.
- Make use of molecular approaches to advance the science of bioremediation, carbon sequestration, renewable energy systems, and ecosystem genomics.
- Expand partnerships with other research institutions and with industry.

3. Terascale Computing and Simulation Science. ORNL is developing the terascale computing and simulation science capabilities that will enable it to become a premier high-performance computing laboratory for DOE's science endeavors.

We are committed to the following actions.

- Secure a multi-teraflops computational platform and infrastructure.
- Increase Laboratory expertise in modeling, simulation, numerical methods, and future architectures.
- Enhance the accessibility of high-performance computing power, both within ORNL and for external partners.
- Expand the scope of the Joint Institute for Computational Sciences.

4. Energy and Environmental Systems of the Future. ORNL will be a key provider of the science and technology needed to support DOE's mission of fostering "a secure and reliable energy system that is environmentally and economically sustainable." Its extensive resources for energy, economic, and environmental R&D will be integrated and focused on developing future energy systems that are environmentally and economically sustainable and expanding the understanding of the health, economic, and environmental impacts of energy choices.

We are committed to the following actions.

- Expand leadership in energy efficiency R&D.
- Advance R&D on clean power systems science and technology.
- Deliver science and technology for understanding carbon sequestration.
- Strengthen analytical capabilities for understanding, assessing, and managing the effects of energy production and use and for evaluating the health, economic, and environmental impacts of energy options.

5. Advanced Materials. ORNL will sustain its position as a leader in advanced materials science and technology underpinning DOE's energy resources mission.

We are committed to the following actions.

- Expand ORNL capabilities and programs in nanoscale science, engineering, and technology.
- Establish the Center for Nanophase Materials Sciences as a DOE Nanoscience Research Center.
- Secure the next-generation Advanced Materials Characterization Laboratory.
- Develop extraordinary tools for materials characterization.
- Extend the Laboratory's synthesis and characterization capabilities.

6. National Security. ORNL will maintain and expand its position as a key resource in the development of national security, law enforcement, and public safety technologies and expertise for federal, state and local governments.

We are committed to the following actions.

- Define, develop, and demonstrate technologies for countering terrorism and for detecting and defeating weapons of mass destruction or mass effects to revolutionize U.S. homeland security.
- Investigate novel scientific approaches and develop new technologies to combat asymmetric warfare and other emerging nontraditional threats.
- Design, develop, and integrate new technologies that respond to national needs in law enforcement, public safety, and emergency management.
- Provide advanced commercial and military logistics technologies and expertise.
- Create a viable Training With Industry Program curriculum with the U.S. Army Acquisition Corps and similar programs with the other military services.

7. University Partnerships. ORNL will increase the value of its science and technology through active involvement of university faculty and students in Laboratory programs.

We are committed to the following actions.

- Expand collaborative programs with the University of Tennessee in areas of mutual interest.
- Continue the joint hiring of scientists and engineers with UT-Battelle core universities, and expand the program to include a wider set of universities.
- Work with Oak Ridge Associated Universities to facilitate research partnerships with its member institutions.
- Develop and extend research partnerships with Tennessee colleges and universities, historically black colleges and universities (HBCUs), and prominent universities across the country.
- Develop the Oak Ridge Center for Advanced Studies to encourage interactions between ORNL researchers and university faculty and students.

Strategic Objective 2: Excellence in Operations and ES&H

We will sustain and improve ORNL's ability to serve the needs of DOE and the nation through responsible stewardship of the resources entrusted to our care.

1. Facilities Modernization. ORNL will construct new facilities and renovate and replace existing facilities to create a modern research campus that enables the conduct of leading-edge R&D.

We are committed to the following actions.

- Carry out a Facilities Revitalization Project to design and construct new facilities and renovate, replace, and dispose of existing facilities in support of ORNL mission assignments and objectives.
- Consolidate Laboratory operations at ORNL's main site.
- Implement a new approach to physical security and facility operations to deliver enhanced performance and staff satisfaction.
- Complete the Uranium-233 Inspection and Repackaging Project.

2. Enhanced Operational Discipline. ORNL will enhance its overall operational performance by improving the discipline and integration of its operations and realigning its security posture to better support accomplishment of DOE's missions.

We are committed to the following actions.

- Upgrade the Laboratory's infrastructure.
- Enhance the Laboratory's cyber security effectiveness.
- Demonstrate continual improvement in ES&H performance, building on the Laboratory's Integrated Safety Management program.
- Deploy an integrated set of "systems-based" management systems.

3. Maximizing Research Effectiveness. ORNL will drive down the cost of doing business, providing more resources for discretionary investments in capability development and infrastructure revitalization, while establishing the Laboratory as an employer of choice in the region and in the research community.

We are committed to the following actions.

- Reduce costs by $30 million by achieving a composite cost multiplier of 1.7 by the end of FY 2003.
- Streamline business operations.
- Attract and retain employees with critical skills for mission execution.

Strategic Objective 3: Excellence in Community Service

ORNL will be viewed by its neighbors as a highly valued partner in the region. We will actively participate in improving the quality of science and mathematics education, supporting the community's civic and cultural activities, and contributing to economic growth.

1. Community Involvement. We will be recognized within the region as a good corporate citizen.

We are committed to the following actions.

- Work with stakeholders to ensure the long-term financial stability of the American Museum of Science and Energy.
- Enrich the community through a set of legacy investments.
- Manage a program of employee volunteerism in community activities.

2. Science and Mathematics Education. We will invest in efforts to improve science and mathematics education in Tennessee.

We are committed to the following actions.

- Purchase state-of-the-art science laboratories for area high schools and middle schools.
- Become a premier sponsor of science and mathematics competitions in Tennessee schools.
- Expand opportunities for Tennessee teachers to participate in the Academy for Teachers of Science and Mathematics at the University of Tennessee.

3. Economic Development. We will encourage the formation and growth of businesses that enhance the regional economy by drawing on ORNL resources in knowledge and technology and on UT-Battelle investments in economic development.

We are committed to the following actions.

- Establish special terms and conditions in partnership agreements to favor formation or continuation of East Tennessee companies.
- In partnership with Technology 2020, use the Center for Entrepreneurial Growth to support the creation and development of businesses based on ORNL knowledge and technology.
- Expand technical assistance to business and industry.
- Foster the development of an entrepreneurial culture at ORNL.

4 • Major Laboratory Initiatives

To extend the nation's capabilities in key areas of science and technology, the Oak Ridge National Laboratory (ORNL) proposes major initiatives in

- neutron sciences,
- complex biological systems,
- terascale computing and simulation science,
- energy and environmental systems of the future,
- advanced materials, and
- national security.

These initiatives will enhance ORNL's ability to support the missions of the Department of Energy (DOE), as indicated in Table 4.1. Research topics associated with these initiatives have been identified as target areas for Laboratory Directed Research and Development (LDRD) funding (see Sect. 5.7).

These initiatives are provided for consideration by DOE. Inclusion of an initiative in this plan does not imply DOE approval of or intent to implement the initiative.

Table 4.1
Support for DOE missions

	DOE mission area			
Major Laboratory Initiative	Science	Energy Resources	Environmental Quality	National Nuclear Security
Neutron Sciences	S	M	M	M
Complex Biological Systems	S	S	M	M
Terascale Computing and Simulation Science	S	S	S	S
Energy and Environmental Systems of the Future	S	S	M	
Advanced Materials	S	S	M	M
National Security			M	S

S = Strongly supportive.
M= Moderately supportive.

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; they are uniquely sensitive to the light atoms that make up much of the natural world; and, because they are highly penetrating, they can be used to probe deep inside materials nondestructively, an application of obvious interest to industry, medicine, and the military. 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 for environmental, commercial, and forensic analyses.

ORNL's strengths in neutron sciences 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, isotope production, materials irradiation testing, and neutron activation analysis. Research at ORELA concentrates on nuclear astrophysics and basic neutron properties (e.g., neutron electric polarizability). ORELA is also used for measurements that support DOE's Nuclear Criticality Safety Program (see Sect. 5.3) 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. Neutron activation analysis 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 Neutron Sciences Initiative to ensure that the Laboratory continues its stewardship of neutron science in support of DOE's missions. This initiative has two major elements: design and construction of the SNS, a next-generation spallation neutron source facility, in collaboration with five other DOE national laboratories, as described in Sect. 4.1.1, and upgrades and refurbishment of the HFIR, which will greatly enhance the neutron science capabilities of the world's highest-power research reactor and extend its life well into the 21st century, as discussed in Sect. 4.1.2.

In addition, ORNL is preparing to take advantage of these new scientific tools and to integrate neutron science into research programs across the Laboratory. ORNL is investing a portion of its LDRD budget to developing neutron science capabilities (see Sect. 5.7).

4.1.1 • Spallation Neutron Source

The Spallation Neutron Source (SNS) is an accelerator-based, next-generation neutron scattering facility that is under construction on the Oak Ridge Reservation. It will produce neutron beams that are 12 times as intense as those available from any existing pulsed source, enabling researchers to "see" never-before-observed details of physical and biological materials, ranging from high-temperature superconductors to proteins. The SNS is the top-priority project of DOE's Office of Science (DOE-SC), which has committed nearly $565 million through FY 2001 for its design and construction. It will play a key role in supporting DOE's goals and strategies in science.

Neutrons will be produced at the SNS by bombarding a mercury target with 1-GeV protons. The protons will be produced by an accelerator system consisting of a hydrogen ion source, a linear accelerator (linac), and an accumulator ring that delivers pulsed proton beams with an average power of up to 2 MW, at a frequency of 60 pulses per second, to the mercury target. Under these conditions, a typical proton will release 20 to 30 neutrons through a nuclear reaction process called spallation. The neutrons will be slowed to useful energies in water or supercritical hydrogen moderators and guided into experimental areas, where they will be used in neutron scattering experiments.

When operational, the SNS will serve 1000 to 2000 users each year; thus, its performance requirements and instrumentation needs are being determined in close collaboration with the scientific user community. Workshops and meetings of researchers who use neutron scattering techniques provide valuable input. A process for instrument selection and inclusion in the project baseline has been developed and implemented. The SNS Instrument Systems group has developed or is developing concepts for 12 different neutron scattering instruments to provide best-in-class capabilities.

The SNS project began in FY 1996, when DOE's Office of Energy Research (now DOE-SC) directed ORNL to initiate research and development (R&D) and conceptual design studies. To carry out these studies, ORNL formed a collaborative arrangement with four other national laboratories: Argonne, Brookhaven, Lawrence Berkeley, and Los Alamos. This SNS collaboration, which will continue through the project's construction and commissioning, accesses DOE's best technical expertise and newest technologies, as well as its vast experience with user programs involving scientists and engineers from universities, industry, government laboratories, and institutions in other nations. In March 2000, the Thomas Jefferson National Accelerator Facility joined the SNS partnership.

The SNS conceptual design report (CDR) was completed in May 1997. Extensive reviews of the CDR endorsed the SNS partnership, its reference design, technical scope, cost, schedule, and collaborative management approach.

Title I design and construction activities began in October 1998. The final environmental impact statement (DOE/EIS-0247) analyzing the proposed ORNL site and alternative sites for the SNS was completed in April 1999, and a Record of Decision identifying Oak Ridge as the preferred site for the SNS was issued in June 1999. Groundbreaking ceremonies for the SNS were held in December 1999. A contract for SNS excavation was awarded in April 2000, and site mass excavation and grading were completed in November 2000 with approximately 1.2 million cubic yards of earth removed and recompacted. Installation of 900 steel pilings for the target building (see Fig. 4.1) is complete, and foundations are being constructed (see Fig. 4.2). At the end of FY 2000, approximately 60,000 hours of construction had been completed without injury or environmental incidents. This outstanding environmental and safety performance continued in FY 2001 with no lost workday cases, three minor recordable incidents, and no environmental incidents in more than 325,000 hours of construction work. Design tasks are progressing on schedule, with 69% complete through September 2001.

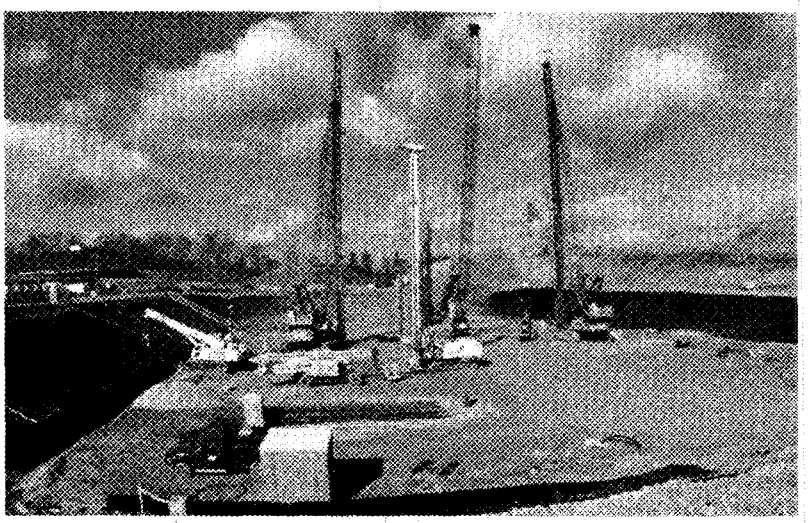


Figure 4.1
Installation of steel pilings for the Spallation Neutron Source.

Open houses in April 2000 and May 2001 have provided information about the project to stakeholders. The May 2001 event was attended by Congressional representatives, DOE officials, and members of local communities.

FY 2002 funding for the SNS project is $291.4 million ($276.3 million for construction and $15.1 million for related R&D and Pre-Operations). Table 4.2 presents the SNS funding profile. The project is on schedule for completion in June 2006.

Table 4.2
Funding profile for the Spallation Neutron Source by fiscal year
[budget authority (BA) in millions of actual year dollars]

Prior years	2000	2001	2002	2003	2004	2005	2006	**Total**
168.5	117.9	278.0	291.4	225.0	143.0	112.9	75.0	**1,411.7**

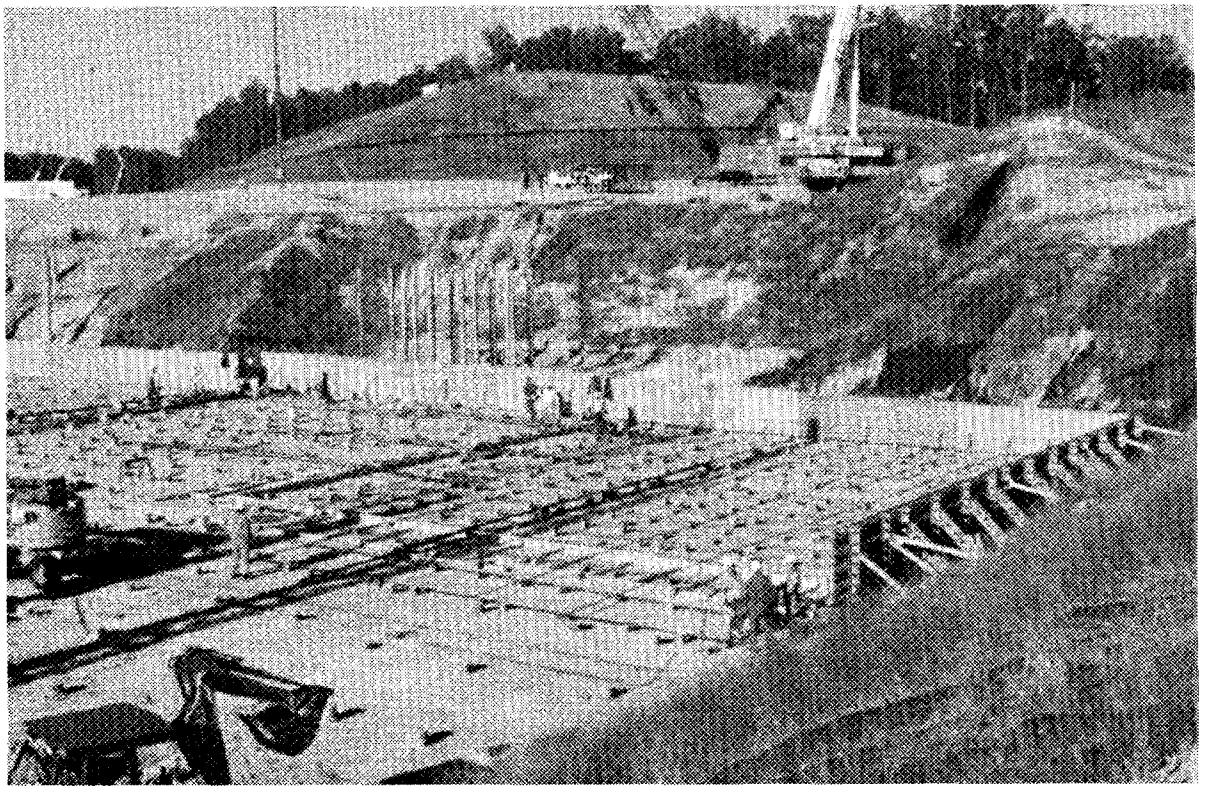


Figure 4.2
Construction of foundations at the SNS site.

4.1.2 • High Flux Isotope Reactor Upgrades

The High Flux Isotope Reactor (HFIR) is among the world's best research reactor facilities. Its flexible design allows it to serve multiple missions—neutron scattering, isotope production, materials irradiation, and neutron activation analysis—and when operating at 85 MW, HFIR produces the world's highest peak thermal neutron flux, 2.3×10^{15} neutrons per square centimeter per second.

HFIR was shut down October 1, 2000, for a beryllium-reflector replacement. The outage provided an outstanding opportunity to install larger beam tubes and new and improved instrumentation for neutron scattering. On November 30, 2001, ORNL received DOE approval to restart HFIR, and currently, operations are resuming.

Improvements to HFIR's research capabilities will continue during FY 2002 and FY 2003. The Office of Basic Energy Sciences has provided $3 million for the construction of the small-angle neutron scattering (SANS) guide hall and is also supplying support for the installation of the cold neutron source and instrumentation. These endeavors will be completed during FY 2002 and FY 2003. The SANS guide hall will provide the necessary space to support a new 20-m SANS instrument and a new 16-m biological SANS instrument, which will be dedicated to biological research. The cold neutron source will allow HFIR to support leading-edge cold neutron research that could result in key new discoveries and applications involving polymers, plastics, alloys, and biochemical systems.

The performance of the upgraded HFIR will be comparable to the best in the world for cold and thermal neutron scattering. It will have 15 state-of-the-art neutron scattering instruments with thermal or cold neutron beams. Its neutron scattering capabilities will complement those of the SNS and will help restore U.S. leadership in neutron science. In addition, the upgraded HFIR will maintain its exceptional capabilities for isotope production, materials irradiation, and neutron activation analysis.

A large neutron guide hall that would extend the HB-2 beam line to as many as 15 instruments and would allow many more users to be accommodated has been proposed. This guide hall would provide more space for instruments in a low-background area outside the reactor building. It would also provide office and laboratory space for outside users and ORNL researchers. Other proposed changes would improve access for radioisotope production and would enhance the neutron activation analysis mission.

4.1.3 • Joint Institute for Neutron Sciences

The Joint Institute for Neutron Sciences (JINS) has been established by ORNL and the University of Tennessee (UT) to serve as an intellectual center for the neutron sciences and to promote the use of neutron beam facilities at SNS and HFIR. The user community has provided input on JINS since 1998, when the concept was introduced at the SNS Instrumentation Workshop held in Knoxville. JINS will be located in the SNS laboratory/office complex and in a housing and conference facility to be constructed near SNS using funding from the state of Tennessee. As the user community at HFIR grows and the SNS begins operation, it is expected that additional universities, government laboratories, and companies will become affiliates of JINS.

JINS will be an intellectual focus for the neutron science community and will enhance and support research using SNS and HFIR. JINS will foster joint faculty positions between ORNL and its university partners and will assist multi-institutional research teams in developing new applications involving neutron scattering and other uses of neutron beams. Fellowship and sabbatical programs will draw neutron scientists from institutions all over the world for interactions with the resident staff and user communities. JINS and its partners will organize study teams that explore emerging scientific challenges that can be addressed using neutron scattering and complementary techniques and will conduct workshops on neutron scattering applications. JINS scientists and support staff will also collaborate with their counterparts at the Center for Nanophase Materials Sciences.

4.2 • Complex Biological Systems

ORNL is developing a significant program in complex biological systems that builds on established programs and expertise in the life and environmental sciences. The Complex Biological Systems Initiative incorporates innovative applications of computational, physical, chemical, and engineering science, as well as special facilities and resources in analytical technologies, to advance the understanding of biological systems. This initiative engages organizations and disciplines across the Laboratory.

Biological research has been revolutionized by advances in molecular biology, bioanalytical technologies, and computational science. There is now an increasing focus on taking advantage of these new capabilities, and the information derived from comparative genomics, to understand the complex interactions, pathways, balances, and control mechanisms of biological systems—from the molecular level through single-cell systems to human biology and physiology to the complex interdependences between living organisms and their environments.

This initiative draws on programs in comparative and functional genomics, structural biology, and computational biology and bioinformatics. It focuses ORNL's distinctive expertise and facilities in mammalian genetics, biochemistry, environmental microbiology, plant genetics, gene expression, analytical technologies, computational science and applied mathematics, physical sciences, and engineering on the challenges of observing and understanding the functioning of complex biological systems.

Specific applications include areas of critical interest to DOE missions—such as human susceptibility to low-dose radiation and other environmental exposures, bioremediation, carbon sequestration, and renewable and alternative energy sources—but also cover systems issues related to human disease, which are of interest to the National Institutes of Health (NIH).

The initiative is designed to establish a significant resource in support of a new program, "Genomes to Life" (GTL), proposed by the DOE-SC Office of Biological and Environmental Research

(OBER) and the DOE-SC Office of Advanced Scientific Computing Research.[1] The GTL R&D program will define the direction of DOE contributions to the global life sciences enterprise for the next decade and beyond. The GTL plan describes four goals:

- identify life's molecular machines, the multiprotein complexes that carry out the function of living systems;
- characterize the gene regulatory networks and processes that control life's molecular machines;
- characterize the functional repertoire of complex microbial communities in their natural environments; and
- develop computers and other computational capabilities needed to model the complexity of biological systems.

Five areas that are key to the success of the GTL program will be pursued through the Complex Biological Systems Initiative: comparative and functional genomics, proteomics and structural biology, the microbial cell, biological systems analysis, and predictive toxicology.

Comparative and functional genomics. Molecular and genetic tools are employed to produce mutations in the mouse, and a battery of phenotype screens, computational tools, and analytical technologies are used to establish the function of the affected genes. Novel approaches are being developed to screen animals for new phenotypes, enhance the information obtained, and increase the throughput of phenotype screening. This activity is supported by the Mouse Genetics Research Facility, which includes a colony of approximately 70,000 animals with a large number of known mutations.

Proteomics and structural biology. ORNL structural biology and functional genomics resources are being employed to understand complex structure-function relationships of proteins in mammals, microbes, plants, and model organisms such as mice, zebrafish, and yeast. Particular emphasis is placed on the identification of modifications in proteins that can affect the formation of protein complexes that are critical to cell signaling processes. This activity is supported by a new user facility, the Center for Structural Molecular Biology, which integrates ORNL's special expertise in biological mass spectrometry, computational biology, and small-angle neutron scattering of proteins and protein complexes.

Microbial cell. Understanding gene function in microbial populations *in situ* integrates genomic approaches for analyzing complicated metabolic pathways, regulatory networks, various cellular processes, and the relationship between microorganisms and their environments. Included in this area is the study of organisms functioning under extreme environmental conditions. Different organisms have unique strengths and weaknesses for studies of different aspects of complex but evolutionarily conserved pathways and systems; as a result, studies of a range of organisms are necessary to understand the below-ground and surface microbial ecosystems. In addition, the complex regulation of community activity requires studies of whole communities for understanding of microbial interactions. *In vitro* and whole-organism approaches to be used for complex pathway analysis include new experimental and computational methods to produce, exploit, compare, or integrate information from several organisms to explain and understand complex shared pathways.

Biological systems analysis. Biological systems analysis encompasses methods that support systems analysis approaches based on biological data, using genetic and molecular approaches to identify both interactions in networks and temporal changes in the functional roles of specific gene products in cells. Advanced computational algorithms and databases developed over the past decade and new computational platforms that can be used to model organismal physiology and ecosystem dynamics are also of interest. The ORNL Laboratory for Comparative and Functional Genomics, environmental biotechnology capabilities, microarray and gene expression capabilities, and computational biology including comprehensive comparative genome analyses and tools for protein classification and structure prediction will be used to advance the modeling and analysis of complex biological systems. The Terascale Computing and Simulation Science Initiative (see Sect. 4.3) will provide new capabilities to support this area.

Predictive toxicology. Scientific advances from the Human Genome Project, subsequent programs in microbial and other genomes, and structural biology provide a foundation for understanding

[1]For more information, see ⟨http://doegenomestolife.org⟩.

the genetic and molecular basis of toxicology. Predictive toxicology, for both human and animal exposure to chemicals in the environment, can be associated with specific gene systems. Many of these gene systems are evolutionarily conserved, and these gene systems are ubiquitous—thus permitting comparative toxicology.

The Complex Biological Systems Initiative builds on ORNL's strong programs in functional genomics and proteomics (see Sect. 4.2.1), structural biology (see Sect. 4.2.2), plant and microbial genomics (see Sect. 4.2.3), and computational biology and informatics (see Sect. 4.2.4), and it involves significant collaboration with other DOE laboratories and other institutions. Additional components include the Center for Systems Biology (see Sect. 4.2.5), which is under development with support from OBER, and the University of Tennessee (UT)–ORNL Joint Institute for Biological Sciences (see Sect. 4.2.6). Funding projections for the Complex Biological Systems Initiative are shown in Table 4.3. (These projections do not include capital funding for the Center for Systems Biology, which is presented in Sect. 4.2.5.)

Table 4.3
Funding projections for Complex Biological Systems Initiative by fiscal year
(in millions of dollars)

	2001	2002	2003	2004	2005	2006
Functional genomics and proteomics	6.0	9.0	10.0	11.0	11.0	11.0
Center for Structural Molecular Biology	1.1	2.0	2.5	3.0	3.0	3.0
Plant and microbial genomics	2.0	2.5	3.0	4.0	4.0	4.0
Computational biology and bioinformatics	3.0	4.0	5.0	6.0	6.5	6.5
Total	**12.1**	**17.5**	**20.5**	**24.0**	**24.5**	**24.5**

Note: These projections include funding from DOE and from other sponsors. They do not include capital funding for the Center for Systems Biology, which is presented in Sect. 4.2.5.

4.2.1 • Functional Genomics and Proteomics

Biologists have studied gene function for many years, but much of this research has been slow, costly, and directed at single genes. Access to the powerful reagents resulting from the Human Genome Project is changing this situation. In this new era of biomedical research, it is possible to perform experiments in functional genomics—that is, to determine the function of genes and systems of genes on a genome-wide scale.

Researchers can study functional genomics in humans by using genome information from model organisms, which provide rich scenarios for experimental research. The mouse, with its genetic and physiological similarities to the human and its extensive comparative genetic linkage map, is a leading model organism for determining human gene function. A wide variety of genetic and molecular manipulations are possible in the mouse, making it a powerful research organism for studies of functional genomics.

Other organisms are also being intensively studied. With completed DNA sequences for plants and microbes (see Sect. 4.2.3), researchers have opportunities to work on gene networks and gene interactions in systems where all the genes are known. Work on other model organisms also opens related research areas that are important to DOE, such as the identification of organisms in the environment and the genetic manipulation of organisms to help mitigate environmental problems.

The availability of complete DNA sequences for many organisms also enables entirely new lines of scientific inquiry into the nature of the proteome, the proteins encoded by the genome. Thus, an important aspect of determining gene function is the characterization of the vast number of proteins expressed by the genome, including the determination of both the structure of a particular protein and its role in the organism. Proteomics research programs are being planned by DOE under the GTL umbrella

and by other agencies, drawing on new high-throughput assays to identify normal and modified proteins by mass spectrometry and to determine the structures of proteins and protein complexes with X-ray crystallography, nuclear magnetic resonance (NMR) spectroscopy, mass spectrometry, neutron scattering techniques, and computational tools.

ORNL is combining the unique strengths of its research programs in mouse genetics and mutagenesis with its resources in structural biology and analytical technologies (see Sect. 4.2.2), plant and microbial genomics (see Sect. 4.2.3), and computational biology and bioinformatics (see Sect. 4.2.4) to address critical issues in functional genomics and proteomics. This approach is based on the conviction that genetics and protein studies should be viewed as integral components of an overall strategy to understand protein function in the context of the whole organism and to define this function at the molecular level.

The intent of the Functional Genomics and Proteomics Program is to maximize ORNL's ability to (1) assign both biochemical and organismal function to genes and proteins, (2) define interacting protein pathways at the molecular level, and (3) establish the role of proteins in the whole organism. In summary, the goal of the program is to understand protein function in the context of the whole organism and to define this function at the molecular level by combining advanced methods in mouse mutagenesis with the development of new concepts for functional genomics and proteomics technologies. Although the focus of this effort is not directly related to drug discovery, the developed tools will be applicable to this field. By working with other research groups at universities and other national laboratories, ORNL will ensure complementarity with related programs in functional genomics and proteomics and will continue to make its resources and technologies available to the scientific community.

ORNL will strengthen existing collaborations, form new collaborations, and serve as a resource to research groups at other national laboratories and in academia and industry. The Tennessee Mouse Genome Consortium supports collaborations with Meharry Medical College, St. Jude Children's Research Hospital, the University of Memphis, the University of Tennessee (in Knoxville and Memphis), and Vanderbilt University Medical Center; a five-year, $12.7 million grant from the National Institutes of Health, announced in October 2000, will support the consortium's neuromutagenesis program. The Merck Genome Research Institute has initiated a research project through the Joint Institute for Biological Sciences (see Sect. 4.2.6), and several new projects are being discussed.

Activities are also under way to establish collaborative efforts with pharmaceutical and biotechnology companies. An R&D consortium involving several industry partners has been organized by the Gene Research Access Corporation (GENRAC), an organization established to facilitate private-sector investment in functional genomics research at ORNL and UT. The consortium will focus on identifying new mouse models for human genetic diseases and novel methods to identify disease phenotypes for use in discovery research programs and other purposes of the partners.

4.2.2 • Structural Biology

Structural biology is a rapidly growing field with a burgeoning impact on basic and applied biology. ORNL has combined its existing strengths in neutron sciences, mass spectrometry, and computational biology and is making them available to a broad user community in the biological sciences through the new Center for Structural Molecular Biology (CSMB), which is funded by OBER. The CSMB will be a key component of the proposed Center for Systems Biology (see Sect. 4.2.5).

The cornerstone of the CSMB is a small-angle neutron scattering (SANS) facility to be constructed at ORNL's High Flux Isotope Reactor (HFIR). SANS is an important tool for studying molecular conformations and interactions. It provides insight into the molecular basis of communication pathways that achieve coordinated function by identifying specific chemical groups that interact with the environment and with molecular networks involved in binding and activation sequences. It can also provide information on the dynamics of a biomolecule in solution and complements high-resolution structural information from X-ray crystallographic and nuclear magnetic resonance data. SANS will be a key tool for understanding the cellular-level communication that is the basis for protein function and, thus, gene function.

The CSMB takes advantage of the opportunity afforded by the HFIR upgrade project (see Sect. 4.1.2), which includes the construction of the nation's "brightest" long-wavelength neutron source. A SANS instrument and associated resources specifically designed for the study of biological systems can be economically developed and built as part of this upgrade; OBER is providing nearly $6 million for such an instrument, designated Bio-SANS. The Bio-SANS, which should be operational by June 2002, will incorporate both high flux and a large-area (1-m^2) detector to collect data over a wider solid angle to enhance the study of biological molecules. The resulting facility will provide the U.S. biological community with state-of-the-art capabilities in SANS, rivaling the world's best biological facilities at the Institut Laue Langevin in France.

The CSMB also leverages ORNL's well-established biological mass spectrometry and computational resources, providing the biological community with additional tools that complement structural information obtained from SANS. For example, modifications to proteins can profoundly affect both the structure and the function of biomolecules. Mass spectrometry can provide information on both the extent of these modifications and the sites of attachment. Computational modeling can support conformational changes observed with SANS. In addition, for uncharacterized proteins, computational methods can be used to identify fold families and to build models from related known proteins before SANS analysis. Capabilities within the CSMB will complement resources at other structural biology facilities, such as synchrotron X-ray crystallography centers, to provide a more complete picture of the structure of biological molecules and their interactions in complex systems.

The CSMB will extend its capabilities to programs within the DOE community and to other government, academic, and industrial laboratories. An advisory panel of distinguished scientists provides guidance to the director and staff of the CSMB. A CSMB User Group has been created to give advice on equipment and capabilities to be included in the CSMB and to establish guidelines for operation. An important aspect of the CSMB will be the training and education of students and scientists in the technologies within the CSMB. A wide range of opportunities for scientists and students working in the field of structural biology will be provided, including extended visits for experimental work, short courses, workshops, and scientific meetings. The Joint Institute for Biological Sciences (see Sect. 4.2.6) will facilitate many of these collaborative opportunities.

The Bio-SANS facilities at the HFIR will be located as far as possible from other instruments to achieve the low background required for biological studies. Adjacent laboratory facilities will be available for final preparation of samples. Data acquisition and reduction capabilities will be integrated into instruments, and ORNL staff will be available to support users.

CSMB users will also have access to the following resources:

- other neutron-based tools at the HFIR, including another SANS instrument designed for studying materials with higher resolution and a reflectometer that can be used to study biomolecular monolayers and thin films;
- resources in biological mass spectrometry, including two high-performance Fourier transform ion cyclotron resonance mass spectrometers and a number of other instruments equipped with electrospray and matrix-assisted laser desorption sources;
- resources in computational biology and informatics (see Sect. 4.2.4), which can be used for modeling, prediction, and database use;
- sample preparation facilities to support SANS and mass spectrometry experiments; and
- support services through the Joint Institute for Neutron Sciences.

In the longer term, the capabilities afforded by the Spallation Neutron Source (SNS; see Sect. 4.1) will create new opportunities in structural biology with improved techniques in neutron scattering. The CSMB will jointly sponsor a workshop with the Joint Institute for Neutron Sciences in mid 2002 to assess research opportunities in structural biology at SNS. Structural biologists from around the world will be invited to participate in this workshop.

The CSMB fills an important niche in the spectrum of scientific tools required to perform comprehensive structure-function experiments. It is designed with specific interfaces to the neutron crystallography center at Los Alamos National Laboratory so as to jointly serve and grow the structural

biology community that takes advantage of the unique features of neutron sources. It is unique in its combination of high-flux cold neutrons for SANS, world-class resources in computational biology, and a pioneering mass spectrometry facility.

4.2.3 • Plant and Microbial Genomics

The availability of new genetic information and the development of new tools (e.g., sequencers and robotic systems) that allow for the gathering of this information on a large scale are creating new opportunities in plant and microbial genomics at ORNL.

Microbial activities, sponsored by DOE-SC, the DOE Office of Environmental Management, and the Office of the Deputy Administrator for Defense Nuclear Nonproliferation (DOE-NN) within the National Nuclear Security Administration, build on the Laboratory's long-term involvement in environmental monitoring and bacterial isolations. ORNL's work in environmental monitoring expanded to include biosensors, now a key area of expertise. Efforts in bacterial isolations identified unique extremophile bacteria that represent resources for future projects and fostered the development of molecular expertise that supports new efforts in functional microbial genomics. Investment of capital resources in equipment for molecular-level explorations also supported the development of expertise and has set the stage for future projects and further expansion into functional genomics.

The Natural and Accelerated Bioremediation Research (NABIR) Field Research Center on the Oak Ridge Reservation (see Sect. 5.1.2.2) will provide new opportunities to understand the interactions of microbes with groundwater and soil, complementing work on microbial genomics. It will also generate data that can be incorporated into the mathematically based numerical models that are an important tool in predicting and planning groundwater management programs and remediation strategies, and it will provide opportunities for comparing computational predictions of bioremediation techniques with actual outcomes.

NABIR investigators doing field work on FRC plots currently conduct their own site-specific modeling. ORNL is assisting investigators with these modeling efforts by providing data and information, such as model input parameters and grids from previous Oak Ridge modeling efforts. The FRC is available to conduct larger scale modeling that covers and integrates data from several NABIR field plots as the need arises.

Arrays of DNA probes are expected to become a foundation for work on microbial pathways, gene expression, and community structure analysis. ORNL will continue to play a significant role in the development of these DNA arrays, which support work that addresses fundamental questions related to DOE missions. For example, metal-reducing bacteria are of interest for remediation of waste sites, for carbon sequestration (e.g., production of carbonate minerals), and for production of novel materials (e.g., cobalt-doped magnetite). DNA arrays that monitor the expression of all of the genes of *Shewanella oneidensis* MR-1, an important and versatile strain of metal-reducing bacteria, are being constructed. Future applications include monitoring microbial communities, assaying background bacterial populations in the air (needed for work on chemical and biological agents in support of DOE-NN), and supporting the discovery and characterization of infectious agents.

In plant genomics, the complexity of the interactions among metabolic pathways, integrative gene expression, and the environment currently limits our ability to make predictions about individual plant growth and ecosystem responses to the environment. Characterizing gene function through functional genomics and differential display technologies, in combination with conventional studies of plant physiology, ecosystem function, and landscape modeling, provides a means of understanding complex plant-based biological systems. Molecular dissection of complex traits will allow the isolation and use of genes that control environmentally and economically important characteristics. A proposal to initiate scoping studies and multi-institutional planning will be prepared and submitted to OBER during FY 2002. These areas will be developed and explored at ORNL under the sponsorship of DOE-SC and the DOE Office of Energy Efficiency and Renewable Energy, drawing on the availability of state-of-the-art equipment in the development of functional plant genomics.

ORNL is exploring ecosystem genomics, an emerging field of research that combines current expertise in ecosystem studies with the rapidly expanding databases on plant, animal, and microbial genomics. The characterization and understanding of gene expression across trophic, temporal, and spatial boundaries will provide new insights into how organisms interact, how ecosystems function, and how physical, biological, and chemical disruptions affect ecosystem stability and ability to respond to environmental change. Real-time surveys of gene expression, made possible by advances in microarray technology, will be coupled with traditional measures of energy flow, mineral cycling, and succession, providing the foundation for testing of hypotheses.

We will investigate trophic-level interactions among organisms, molecular mechanisms that determine the ability of organisms to adapt to environments, the molecular basis for ecosystem homeostasis, and the identification of basic suites of genes that are required in all healthy, functioning ecosystems. For example, rapid development of bioenergy and terrestrial carbon sequestration technologies, two near-term solutions to mitigating greenhouse gas concentrations, will rely on our understanding of and ability to manipulate the genetics and biochemistry of plants and microorganisms. Research on the genetic basis of carbon allocation in woody plants could lead to enhanced production of wood from trees with a targeted chemical composition. Greater understanding of microbial and molecular control of soil carbon quality and quantity will provide strategies for enhancing soil carbon sequestration.

New tools and approaches in bioinformatics will be needed to deal with new DNA array data and DNA sequence data. One promising approach involves the use of artificial neural networks for pattern recognition. The expansion of this approach from biochemical markers (e.g., specific lipids) to DNA data of various kinds offers promise for increased understanding of the complexity of plant and bacterial communities and their interactions with environmental factors.

4.2.4 • Computational Biology and Bioinformatics

The recent report by DOE's Biological and Environmental Research Advisory Committee (BERAC), *Bringing the Genome to Life*,[2] refers to computation as a "great unifier" of biological research because of its potential for modeling biological systems; managing, analyzing, and recognizing patterns in complex data; and complementing experimental approaches to biology. Computational biology represents a significant opportunity because of DOE's unique high-performance computing resources and programmatic emphasis on scientific areas that rely heavily on computation. The BERAC report strongly emphasizes many different aspects of computational biology and recognizes the increasing need for investment in this area. Particularly strong themes in the report include computational and comparative genomics, protein structure and function, and bioinformatics systems in support of a variety of functional genomics activities. The GTL program document, which is based on the BERAC report recommendations, includes a significant computational biology component.

ORNL has a distinguished history of providing community tools and resources that are well regarded on an international level and has promoted DOE to an unparalleled level of success in bioinformatics and computational biology.[3] Laboratory activities in computational and comparative genomics build on a 10-year record of success, and ORNL continues to provide the community with advanced tools and resources, including Web-accessible tools such as GRAIL (Gene Recognition and Analysis Internet Link), and GRAIL-EXP, PROSPECT (the Protein Structure Prediction and Evaluation Toolkit), Pfam, BEAUTY, the Genome Annotation Pipeline [extensively used by the Joint Genome Institute (JGI)], BLAST, Genscan, repeatmasker, tRNAscan, and others. The Genome Channel furnishes researchers with precomputed views of genomes in a powerful environment for visualization, query, and search of its 30 genomes. At more than 200,000 hits per month, it has found significant use by investigators. The high Web hit rate reflects the importance of these resources to the research community.

Comprehensive sequence-based views of completed microbial genomes ranging from the full genome to the nucleotide sequence level are included in the Genome Channel and Genome Catalog. We

[2] Available at ⟨http://www.science.doe.gov/production/ober/berac/genome-to-life-rpt.html⟩.

[3] For further detail, see ⟨http://compbio.ornl.gov⟩ and ⟨http://genome.ornl.gov⟩.

have developed tools for comparative multiple-genome analysis that offer automated, regularly updated, comprehensive annotation of microbial genomes using consistent methodology for gene calling and feature recognition. The visual genome browser represents around 51,000 microbial GRAIL and 45,000 GenBank gene models. Precomputed BEAUTY searches are included for all gene models, with links to original source material and additional search engines. Comprehensive representation of microbial genomes will require deeper annotation of structural features, including operon and regulon organization, promoter and ribosome binding-site recognition, repressor and activator binding-site calling, transcription terminators, and other functional elements. Sensor development is in progress to allow access to these features. Linkage and integration of the gene-protein-function catalog to phylogenetic, structural, and metabolic relationships also will be developed.

A draft analysis pipeline has been constructed to provide annotation for the JGI's Microbial Genome Program. The first five draft sequences in the pipeline, with many more to come, are the *Nitrosomonas europaea, Prochlorococcus marinus, Rhodopseudomonas palustris, Nostoc punctiforme,* and *Enterococcus faecium* genomes. Multiple gene callers (Generation, Glimmer, and Critica) are used to generate a candidate gene model set. The conceptual translations of these gene models generate similarity-search results and protein family relationships. From these results, a metabolic framework is constructed and functional roles are assigned. Simple and complex repeats, tRNA genes, and other structural RNA genes are also identified. Annotation summaries are available through the JGI microbial genomics Web site; in addition, draft results are being integrated into the interactive display schemes of the Genome Channel and Genome Catalog. ORNL staff members take a lead role in interacting with user groups for each organism being annotated. A streamlined, high-throughput version of the draft pipeline was designed to accommodate the data flood from JGI "Bug Months," which average 2 to 3 megabytes (2000 to 3000 gene models) a day for 30 days.

High-performance computing has played a key role in genome annotation. GIST, the Genome Integrated Supercomputing Toolkit, which has been used to annotate human and microbial genomes, is available on line to the scientific community. GIST is a fault-tolerant, massively parallel computational biology framework developed at ORNL. Key GIST analysis tools running on the IBM SP3 and other ORNL Center for Computational Sciences systems (see Sect. 4.3.1) include MPP-BLAST for sequence comparison, GRAIL-EXP for gene finding, and protein-structure and domain-classification systems, such as PROSPECT and HMM Pfam. Integration of these resources into the genome annotation system has allowed ORNL to analyze, interpret, and update JGI and other microbial genomes for rapid dissemination to the community. This infrastructure was pivotal in generating annotation for the human genome, especially the assembly and analysis of DOE draft chromosomes 19, 16, and 5.

Bioinformatics provides support for functional genomics research in the manipulation of large, complex data sets and the integration of data across multiple laboratories. We provide bioinformatics support for JGI human, mouse, and microbial genome sequencing and annotation and are devising systems for analyzing data and managing information in the ORNL mouse genetics and genomics program, which includes activities within the Tennessee Mouse Genome Consortium. Bioinformatics tools are also being developed to support data storage, statistical analysis, and presentation for RNA expression analysis and to follow mouse mutagenesis experiments.

A number of computational tools have been developed for calculating the structural properties of newly discovered proteins. One is PROSPECT, a threading-based computer program for protein-structure prediction. PROSPECT is unique in that (1) it rigorously solves the globally optimal threading problem, with sidechain-sidechain interactions considered, in an efficient manner (polynomial time); and (2) it facilitates the incorporation of partial experimental data as threading constraints. Work in the second area has included identifying active sites, disulfide bonds, partial distance restraints from nuclear magnetic resonance (with Michael Summers of the University of Maryland–Baltimore County and Engin Serpersu of UT), and mass spectrometry (with Jim Stephenson of ORNL). PROSPECT was ranked among the top six performers in the CASP4 protein-structure prediction contest in both fold recognition and *ab initio* fold prediction (using its ability to identify partial folds).

As emphasized by the BERAC report, the availability of a large number of complete genomes and their gene content raises the possibility of systematically deriving a cell's complex internal structure. In a new research activity, we are addressing the critical need to develop an effective, robust, and potentially automatable methodology to obtain well-founded and well-understood causal descriptions of complex gene networks in biological systems. Using expert systems to provide a comprehensive description of an organism's gene networks, the method under development will integrate gene and regulatory information, results from expression-array experiments, and partial pathway knowledge from other organisms and pathway databases. The description will include both pathway and regulatory relationships and provide a practical network model that can be used to predict behavior. As a proof of principle, the approach is being applied to (1) selected yeast pathways as key eukaryotic models important for human and mouse genomes and (2) the prokaryotic cyanobacteria family being sequenced by DOE because of its importance in photosynthesis and environmental cycles.

4.2.5 • Center for Systems Biology

ORNL is developing a Center for Systems Biology (CSB) to fulfill important needs of the new GTL program proposed by OBER and the DOE-SC Office of Advanced Scientific Computing Research. The CSB will place an emphasis on human susceptibility to the consequences of energy production and use, and it will incorporate ORNL's special facilities and resources in mammalian genetics and genomics, analytical technologies, and computational biology.

Planning for the CSB is under way, and an advisory board is being established. One goal of the CSB is to open the way for significant ORNL participation in the GTL program by integrating and leveraging the Laboratory's distinctive expertise and facilities in

- mouse models for human susceptibility to understand health effects of environmental insults;
- environmental microbiology to understand microbial diversity and to engineer microbial systems relevant to DOE missions;
- computational biology and specialized high-performance computing (HPC) for biological applications, such as the derivation of knowledge from genome sequences, high-throughput protein structure determination by combining HPC with experimental structural biology methods, and dissection of the complexity of networks and pathways in cells and organisms;
- biological mass spectrometry, microarrays, biosensors, imaging, and other analytical technologies to perform high-throughput analyses of proteins, protein complexes, and processes in the cell; and
- structural biology, including neutron scattering and diffraction (HFIR and SNS), mass spectrometry, and computing, through the CSMB (see Sect. 4.2.2).

Our expectation is that the CSB will also become a systems biology resource for the NIH, building on current NIH investments in mouse functional genomics and on other programs under development in computational biology. In addition, the CSB will have a strong industrial research program, building on evolving partnerships, such as the GENRAC consortium. Table 4.4 provides funding projections for the CSB. (Amounts are in addition to those listed in Table 4.3.)

ORNL received $2.5 million in FY 2001 to begin construction of the Laboratory for Comparative and Functional Genomics (LCFG), which will be an anchor facility for the CSB. The design/construction contract for this facility was awarded in August 2001, and construction will begin early in FY 2002. The LCFG is scheduled for completion in 2003. The funding profile for this line item includes an additional $11.4 million in FY 2002 (not included in Table 4.4).

4.2.6 • Joint Institute for Biological Sciences

Through the Joint Institute for Biological Sciences (JIBS), ORNL and UT promote and develop support for collaborative education and research in biological sciences. UT organizations involved in this effort include the Medical Centers, the College of Veterinary Medicine, and the Institute of Agriculture.

The focus of JIBS is to strengthen the partnership between ORNL and UT and expand collaborative efforts in functional genomics, structural biology, analytical technologies (see Sect. 5.1.2.1), and

Table 4.4
Funding projections for the ORNL Center for Systems Biology[a] by fiscal year
(in millions of dollars)

	2002	2003	2004	2005	2006
Operating[b]	2.0	6.0	12.0	15.0	15.0
Capital[c]	1.0	3.0	2.0	2.0	2.0
State of Tennessee funds[d]	8.0	0.0	0.0	0.0	0.0
Total	**11.0**	**9.0**	**14.0**	**17.0**	**17.0**

[a]Indicates both new funding for CSB and funding for ongoing research projects.
[b]Includes both DOE funds and funds from other sponsors.
[c]DOE capital funds for equipment.
[d]For construction of facility to house the Joint Institute for Biological Sciences; see Sect. 4.2.6.

computational biology and bioinformatics. Efforts include the integration of the ORNL-UT Graduate Program for Genome Science and Technology into JIBS.

JIBS will provide new opportunities for applying the complementary capabilities of ORNL and UT to emerging problems in the biological sciences. It will also support the integration of research and education, exposing students to the multidisciplinary approaches needed to understand complex biological systems. A strong interface with the UT Medical Centers is envisioned to support the effective transfer of R&D results to clinical applications, and distance learning capabilities at ORNL and UT will enhance opportunities for national and international participation in research conducted under the auspices of JIBS. Funding from the State of Tennessee will be used to construct a facility to house JIBS as part of the ORNL Center for Systems Biology (see Sect. 4.2.5). It is envisioned that the JIBS facility will house research laboratories, offices, and state-of-the art classrooms with distance learning resources. The laboratories will be equipped with emerging technology tools for advanced biological research provided by and in support of OBER's GTL program. A number of these laboratories will be made available to ORNL–UT research collaborators across the state and outside Tennessee. It is envisioned that private companies will engage in cooperative R&D agreements (CRADAs) with ORNL and place incubator research in some of these laboratories as well.

Workshops with stakeholders to determine desired features are being conducted, and requirements will be developed, reviewed, and documented. The $8 million JIBS facility is scheduled to be constructed in FY 2003.

4.3 • Terascale Computing and Simulation Science

Dramatic advances in the power and performance of computers have opened a pathway to the modeling and simulation of physical situations, thus providing new insights into a host of complex science and engineering problems. Innovative computers now under development are expected to be able to perform as many as 180 trillion arithmetic operations per second (teraflops) by 2004. As the development of more powerful supercomputers continues, advances in processing power must be complemented by advances in computing, communications, and information tools and technologies.

In FY 2001, DOE established the Scientific Discovery through Advanced Computing (SciDAC) Program,[4] a five-year effort to develop the scientific computing software and hardware infrastructure that the Department needs in order to use terascale computers to advance its research programs in basic energy sciences, biological and environmental research, fusion energy sciences, and high-energy and nuclear physics. The SciDAC Program is focused on four key areas:

[4]*Scientific Discovery through Advanced Computing*, Office of Science, U.S. Department of Energy, Washington, D.C., March 24, 2000; available on line at ⟨http://www.sc.doe.gov/images/news_photos/SDAC_Overview_000330.pdf⟩.

- creating a new generation of scientific simulation codes that take full advantage of the extraordinary computing capabilities of terascale computers;
- creating the mathematical and computing systems software that will make it possible for these scientific simulation codes to effectively and efficiently use terascale computers;
- creating a collaboratory software environment that will enable geographically separated scientists to effectively work together as a team and that facilitates remote access to both facilities and data; and
- developing and sustaining a scientific computing hardware infrastructure that is tailored to meet the needs of its research programs. This hardware infrastructure must be robust, to provide the stable computing resources needed by the scientific applications; agile, to respond to innovative advances in computer technology that affect scientific computing; and flexible, to allow the most appropriate and economical use of resources to solve each class of problems.

Because of its programmatic diversity (see Sect. 5), its comprehensive resources in computational and computer science, and its terascale computing facilities, ORNL is uniquely positioned to provide support across all of these areas.

Through our Terascale Computing and Simulation Science Initiative, we will develop and deploy leading-edge computing capability and conduct state-of-the-art R&D in computer and computational sciences in support of SciDAC and other DOE missions and programs. We will develop and operate experimental computing facilities to assess the promise of new computing technologies for scientific applications, and we will apply our computing resources to specific scientific applications, providing opportunities for optimizing the use of terascale computers to address critical science issues.

The primary source of funding for this initiative is the DOE-SC Office of Advanced Scientific Computing Research; some funding for scientific applications is expected to come from other DOE program offices. As described in Sect. 5.7, ORNL is investing a portion of its FY 2002 Laboratory Directed R&D (LDRD) funds in advanced scientific computing, focusing on superscalable algorithms, petascale data analysis, and mathematics and algorithms.

4.3.1 • Terascale Infrastructure

ORNL's Center for Computational Sciences (CCS) is an advanced terascale computing facility that provides state-of-the-art resources for high-performance computational science and computing science research, with additional resources in networking, visualization, and storage. The CCS supports and integrates the development of tools and software to make high-performance computing more effective and accessible; the development and analysis of basic techniques and efficient numerical algorithms for solving large-scale scientific and engineering problems on advanced computer architectures; and research in cluster computing, networking, and storage.

The CCS provides a focal point for ORNL's computational science research, bringing together theoretical and computational scientists, computer scientists, and applied mathematicians who develop and refine the tools needed to make optimum use of computing resources, as described in Sect. 4.3.2. In addition, the CCS computers are increasingly being used for scientific applications; collaborative programs to develop applications software are discussed in Sect. 4.3.3.

With support from the SciDAC Program, we will maintain the CCS as a leading center for unclassified scientific computing. Currently, CCS operates a 1-teraflops IBM Winterhawk system and a 0.4-teraflops Compaq AlphaServer SC system for leading-edge research as part of SciDAC and other DOE applications. We are engaged in installing a 4-teraflops, next-generation IBM Power4 Cheetah for early evaluation and scalability research, as a first step in moving to 10-teraflops capability in FY 2003. We are also exploring collaborations with our laboratory and industrial partners to develop petaflops computers by 2006. This will require substantial advances in hardware technologies, system software, and applications. Toward this end, we are working with Compaq and IBM to obtain a 100-teraflops machine by FY 2004.

ORNL's Facilities Modernization Initiative (see Sect. 7.3) includes the construction of a new 100,000-ft^2 Computational Sciences Building to provide appropriate housing for our state-of-the-art computing facilities. Design work for this building has begun, and it is expected to be ready for occupa-

tion in early 2003. Also being designed is a facility to be constructed with funding from the state of Tennessee that will house the Joint Institute for Computational Sciences (see Sect. 4.3.4).

4.3.2 • Mathematics and Computer Science

To further its broad programs in the development and application of innovative computational systems and tools, ORNL will continue and expand its work in distributed and cluster computing tools, numerical software, applied mathematics and algorithm development, and application-specific tools.

4.3.2.1 • Distributed and Cluster Computing

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

This effort will be of direct benefit to a variety of DOE programs. In particular, these actions will support ongoing programs in materials research, computational chemistry, biology, environmental sciences, neutron science, and bioinformatics.

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

4.3.2.2 • Networking

ORNL's network support strategy has two near-term thrusts. First, ORNL has been identified in the ESnet3 procurement as a major hub (along with the Bay Area, Albuquerque, Chicago, and New York). As a result, the bandwidth of ORNL's connection to other DOE laboratories (and to the greater Internet) will increase from OC3 (155 Mbps) to OC48 (2488 Mbps). In anticipation, the local backbone is being upgraded from a collection of shared 100-Mbps Fiber Distributed-Data Interface (FDDI) rings to a hierarchical Switched Gigabit Ethernet lattice. Second, wireless networking will be made available in ORNL's conference rooms and auditoriums. This will enhance the Laboratory's desirability as a venue for conferences and workshops, at which easy access to the Internet is increasingly expected, and will also give participants in meetings access to critical information through their laptop computers. During the next several months, we will plan and install advanced networking facilities to increase the internal connectivity at ORNL and to provide a higher level of connectivity with other DOE laboratories and collaborating institutions.

4.3.2.3 • Data Management and Storage

New tools to support data-intensive computing will be created to manage the large data sets being acquired, for example, to support research in functional genomics and global climate change.

Developments in data storage and network peripherals will be aimed at securing a balanced computational environment consistent with a multiple-teraflops system. The resulting increase in connectivity will strengthen collaborations within ORNL and across the DOE system of laboratories. ORNL will continue as a partner in the multilaboratory HPSS collaboration (see Sect. 5.4.1), which is pursuing further improvements in the flexibility, performance, features, and usability of this software. Expertise gained through the 1995–97 ORNL-Sandia distributed high-performance computing partnership will be applied to the development of networks operating in the range of 200 gigabytes per second (Gbps).

A distributed storage test bed, known as Probe, connects the National Energy Research Scientific Computing Center at the Lawrence Berkeley National Laboratory and ORNL. Probe is being used to evaluate new storage hardware and software technologies, to improve the performance of storage

systems, and to develop new techniques for distributed access to data over the Internet. ORNL will extend its leadership position in distributed storage research by inviting National Science Foundation and Department of Defense supercomputer centers to participate in the Probe storage test bed.

4.3.2.4 • Tools for Collaboration

ORNL will continue to work with universities and other national laboratories on research issues related to collaborative immersive visualization environments. Issues being pursued include handling and viewing of large data sets, use of parallel and distributed computing to drive immersive environments, interactive steering of high-performance computations, access to remote instrumentation in a virtual environment, virtual televisions and recordings, mapping force and tactile feedback, desktop 3-D environments, use of holography, rapid development of synthetic environments from sensor data, human interactions in virtual reality, and computer vision.

The AccessGrid is a nationwide system that uses the Internet to allow group videoconferencing, sharing of remote applications, and virtual environments. An AccessGrid node will be installed at ORNL to facilitate collaborations with universities and other national laboratories where similar nodes are being deployed.

4.3.3 • Scientific Applications

Applied research projects in high-performance computing at ORNL span the Laboratory's programs, with activities under way in environmental systems, engineering applications, physical and chemical sciences, experimental validation, computational biology and functional genomics, and nanotechnology and neutron sciences. Key areas to be addressed during the planning period are described in Sects. 4.3.3.1–4.3.3.4.

Topical centers provide an environment in which the hardware, software, and policies of the computing center can be tuned to the needs of a particular science community in order to accelerate the process of scientific discovery. A prototype topical center, supporting ORNL's computational materials science research, is under development. By mid-FY 2002, ORNL will be the focal point of two additional topical centers, one in climate prediction and one in computational biology.

ORNL is also heavily involved in the development of four enabling technology centers to support the needs of SciDAC applications and to promote the development of expertise in simulation and modeling. The focus areas of these centers are scalable systems software, common component architectures, large-scale data analysis, and performance monitoring.

4.3.3.1 • Climate Prediction

Working within a multi-institutional research project, ORNL has advanced the use of massively parallel computers for climate modeling through the development of numerical methods and parallel algorithms and the implementation of CCSM, the Community Climate System Model of the National Center for Atmospheric Research, on the IBM RS/6000 SP and the SGI Origin 2000. PCM, the Parallel Climate Model, has also been developed and implemented on ORNL's massively parallel computers, and multiple runs have been completed, making it possible to more fully quantify the uncertainties in climate predictions.

Work to develop new climate models that can take advantage of new levels of supercomputing power continues through DOE's Climate Change Prediction Program and related research projects. A collaborative project spanning four divisions (Energy, Environmental Sciences, Computational Sciences and Engineering, and Computer Science and Mathematics) is aimed at establishing a climate prediction center at ORNL. Plans include coupling general circulation models (GCMs) with interactive carbon and chemistry modules and creating an interdivisional computational grid environment.

4.3.3.2 • Materials

Insights gained from simulations of the properties and behavior of materials, which cost less and take less time than laboratory experiments, are accelerating the development of new, technologically

advanced materials that can improve the efficiency and economy of energy production and use, contribute to new technologies, and lead to new products. Scientists at ORNL are using massively parallel processors and newly developed computational methods to carry out a variety of projects:

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

Further advances in computational capability will extend the ability to predict and tailor the properties of materials, supporting the aims of the Advanced Materials Initiative (see Sect. 4.5).

4.3.3.3 • Fusion Energy Sciences

The fusion research community pioneered the use of nationally networked supercomputing, and modeling and simulation continue to be key tools for developing the knowledge base to support the use of fusion as an energy source. Increased computational power is expected to open the way for detailed three-dimensional (3-D) simulations of a wide range of confinement schemes and plasma phenomena.

Through a new SciDAC project on numerical computation of wave-plasma interactions in multidimensional systems, ORNL will be collaborating with other members of the rf theory community and the computer science community to extend the physics generality of the theories and to attack major unsolved problems in wave-plasma interactions with immediate implications for ongoing experiments. A second SciDAC project, led by Auburn University, engages ORNL researchers in terascale computational atomic physics for the edge region in controlled fusion plasmas.

4.3.3.4 • Genomes to Life

Building on its recent success with the Human Genome Project, DOE has embarked on a new initiative, "Genomes to Life" (GTL), with the mission of developing the capability of understanding and predicting the behavior of single cells and multicellular organisms. This ambitious goal represents decades of biological research. Computational biology and the increased availability of terascale computational power played a key role in the mapping of the human genome, and computational biology will play an even more important role in the GTL initiative as high-performance computational codes are developed to model complex biological systems. More than 100 teraflops will be required to carry out protein structure prediction in one microbial genome, and multipetaflops computing capability and dedicated resources will be needed to model even the simplest of single-cell organisms. A coordinated community effort in structural genomics and computational biotechnology will create a demand for additional high-performance computational tools to address detailed molecular structures and even more complex biological systems.

As part of its strong and rapidly growing computational biology and bioinformatics effort (see Sect. 4.2.4), ORNL has developed DNA sequence analysis tools, other genome informatics resources, and protein classification and structure prediction tools that are widely used by the international biology community. New tools and approaches are being created to address a variety of challenges. The focus is on extending the range of understanding of biological phenomena from molecules to systems to phenotype and organism function. This understanding is critical to DOE's science and environmental quality missions.

ORNL has established a cooperative R&D agreement (CRADA) with IBM to participate in the "Blue Gene" petaflops computer project. Blue Gene will combine massive parallelism and new computer architecture approaches with innovative software to simulate protein folding, providing not only a breakthrough in cutting-edge computing but also an extraordinary tool for exploring fundamental biological processes. As part of this CRADA, ORNL and IBM will share postdoctoral positions and research staff.

4.3.4 • Joint Institute for Computational Sciences

The Joint Institute for Computational Science (JICS) promotes collaborative research between groups at ORNL, the University of Tennessee (UT), and the UT-Battelle core universities and encourages and facilitates the effective use of high-performance computing. JICS will focus on research and education that weave together advanced computation with experiments in the physical, biological, energy, and environmental sciences. ORNL and UT are initiating a new Alliance for Computing and Communications for Excellence in Simulation Science (ACCESS) to broaden the intellectual scope and research activity at both institutions by building on existing collaborations and complementary strengths. As part of this effort, we are working to establish a Southeast Network Research Center involving key universities and institutions in the southeastern United States. JICS will allow joint recruitment in areas of current strength and those expanding the scope of the existing activities. A new facility, funded by the state of Tennessee, will be constructed to house JICS (see Sect. 4.3.1).

4.4 • Energy and Environmental Systems of the Future

4.4.1 • Introduction

ORNL is developing a comprehensive and systematic approach to meeting the growing global need for energy services. This Energy and Environmental Systems of the Future (E^2SF) Initiative addresses the broad challenge, put forward in DOE's mission statement, of fostering "a secure and reliable energy system that is environmentally and economically sustainable."

The United States is well endowed with a variety of energy sources, including substantial fossil fuel reserves, a considerable nuclear power industry, and significant renewable energy resources. Nevertheless, the nation imports about 58% of the petroleum products that it consumes. Moreover, there is concern about the environmental impacts of nuclear and fossil energy and of future energy systems.

The corresponding situation in many parts of the world is far more challenging. Developing countries are experiencing rapid growth in population, energy demand, and the environmental degradation that often results from industrial development. The near-term depletion of fossil energy resources in response to this rapid growth is not sustainable over the long term.

In 100 years, the world population is projected to be at least 8 billion. Meeting the energy needs of this population will be a formidable challenge. Most forecasters are saying that total world energy services must increase by a factor of 3 to 4 in the next 100 years to meet global needs for energy services and eliminate inequities between more and less developed nations.

Accompanying this growing demand for energy is an increasing awareness that the resources and technology systems meeting a very large proportion of current needs are not sustainable. Not only are fossil fuel sources, especially conventional oil and gas, limited in quantity and nonrenewable; it now appears that the issue of emissions—particularly greenhouse gas emissions—may make the continuing use of fossil fuels nonsustainable even while coal remains plentiful. Increasingly sophisticated models are predicting both global warming and increased variation in climate as a result of energy-related actions. Nonsustainable resource use can also lead to widespread pollution, desertification, deforestation, and species extinction.

The combination of these two elements—increasing needs and nonsustainable resources and systems—creates a tremendous challenge. Science and technology can play a major role in increasing the

availability of energy services, but decisions about energy resources and technology choices throughout the world will be governed largely by market forces and to a lesser extent by social concerns about the affordability of energy services and the impacts of energy production, distribution, and use on human health and the environment. The development and deployment of future energy systems with the characteristics listed in Table 4.5 will thus require a thorough understanding of a broad range of scientific advances and technological solutions, economic drivers, and policy issues.

Table 4.5
Characteristics of future energy systems

Characteristic	Definition
Clean	Minimal adverse effects on human health and the environment
Efficient	Significantly more efficient than today's energy services
Affordable	No more expensive than today's energy services
Available	Accessible throughout the world
Abundant	Drawing on plentiful resources

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 and the environment. As a primary performer of environmental sciences for DOE, ORNL also has extensive resources for understanding and addressing the economic costs and benefits and the environmental effects of energy production and use. As a result, the Laboratory is uniquely positioned to attack the long-term, large-scale, multidimensional problem of meeting national and global needs for energy systems that respect human health, are affordable, and have a minimal impact on the environment.

The E²SF Initiative provides a framework and a focus (see Fig. 4.3) for the Laboratory's support of DOE's general goal for energy resources: "Promote the development and deployment of energy systems and practices that will provide current and future generations with energy that is clean, efficient, reasonably priced, and reliable." Through the E²SF Initiative, we will

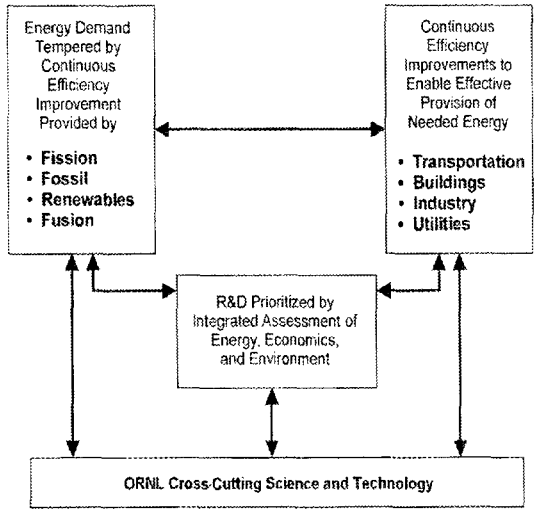


Figure 4.3
Conceptual model for the E²SF Initiative.

- coordinate ORNL's comprehensive activities in energy science and technology, economic analysis, and environmental science and technology;
- define, select, and support new energy development activities, with the aim of developing realistic pathways to a sustainable and affordable energy future; and
- create and use partnerships to bring together complementary resources in addressing this problem.

Funding for the E²SF Initiative will be sought from DOE-SC and the DOE Offices of Energy Efficiency and Renewable Energy, Fossil Energy, and Nuclear Energy, Science, and Technology. Funding projections are being developed.

4.4.2 • Approach

The E²SF Initiative is envisioned as a focused program that comprises

- integrated R&D to develop future energy systems that are cost-effective and affordable and that respect health and the environment;
- a targeted effort in fundamental science to support improved understanding, assessment, and management of the health, environmental, and economic consequences of energy choices, with particular emphasis on how energy use affects economic competitiveness and environmental systems; and
- the development and application of R&D capabilities to evaluate technological, environmental, and socioeconomic factors in the development and deployment of systems for the safe, reliable, and efficient generation, storage, and distribution of energy.

Partnerships are a critical element of the E²SF Initiative. The multidisciplinary nature of the complex problems encompassed by E²SF presents a number of opportunities for teaming and collaboration, both within the Laboratory and with other organizations that possess complementary capabilities.

4.4.3 • Resources

ORNL has been a leader in R&D at the intersection of energy, economic, and environmental issues throughout its history. The Laboratory's assets include programs in nuclear energy, energy efficiency and renewable energy, fossil energy, and fusion energy; cross-cutting programs (e.g., in chemical sciences and technologies, engineering sciences, instrumentation and measurement science, and materials sciences) that address fundamental questions about energy; environmental research programs focusing on global change, environmental processes and systems, the effects of energy development and use, and resource utilization; strengths in environmental management sciences and environmental technology development; and energy-related assessment and information activities characterized by distinctive capabilities in the analysis of economic and policy factors. The strength and breadth of ORNL's capabilities represent an important and defining characteristic of the E²SF Initiative.

Other ORNL resources are available to support the E²SF Initiative. The Oak Ridge National Environmental Research Park and unique experimental field facilities in the park support large-scale environmental process research (see Sect. 5.1.2). Facilities such as the Advanced Propulsion Technology Center, the Bioprocessing R&D Center, the Buildings Technology Center, the High Temperature Materials Laboratory, and the National Transportation Research Center support a broad range of energy-related R&D. Strengths in separations science and chemical processing (see Sect. 5.2.2) represent a notable resource for energy efficiency and pollution prevention. ORNL's computational capabilities are a key asset for studies of energy-related topics, such as climate variability and climate change, combustion, and fusion energy sciences.

The E²SF Initiative is also linked to other major Laboratory initiatives. Enhancement of ORNL's neutron science capabilities (see Sect. 4.1) will support investigations of new materials for energy systems, molecular-level studies of environmental chemistry, and analysis of protein structure in support of new means of energy production and evaluations of energy impacts. The E²SF Initiative draws on ORNL's Complex Biological Systems Initiative (see Sect. 4.2) for information about the biological and environmental impacts of energy choices, for new ways of remediating environmental contamination, and for new resources for clean energy production. Advances in terascale computing and simulation science (see Sect. 4.3) will support more accurate predictions of climate variation and provide insight into energy-related materials and processes. The Advanced Materials Initiative (see Sect. 4.5) will improve the understanding of materials and materials-related phenomena that underpin energy technologies.

Collectively, ORNL's resources make major contributions to meeting the challenges advanced in DOE's energy R&D portfolio (see Sect. 4.4.4.1). The breadth of these resources and their integration of basic research, applied research, and technology development are important assets for the E²SF Initiative.

4.4.4 • Planned Activities

In FY 2002, ORNL will

- develop a coordinated view of its capabilities in energy science and technology, global climate science and carbon management, and analytical methods and engineering to provide an integrating focus for the E²SF Initiative;
- secure new capabilities by investing LDRD funds to explore critical research needs in developing and analyzing the scientific underpinnings for new, cleaner energy technologies and in analyzing the socioeconomic and environmental consequences of new energy technologies;
- pursue the development of experimental facilities that will extend our capabilities across the spectrum of E²SF activities; and
- build strategic partnerships, within and beyond the Laboratory, to leverage our capabilities and accelerate the understanding of key energy issues.

The results of these tasks will be used in constructing a long-term R&D program in E²SF.

4.4.4.1 • Integrating Activities in Energy, Economics, and Environment

As a multiprogram science, technology, and energy laboratory, ORNL is engaged in a broad variety of DOE-sponsored programs that address the challenges presented in the Department's energy R&D portfolio: producing clean fuels, developing advanced energy systems, enhancing utility infrastructure, and providing the energy base for clean, resource-efficient industries.

DOE sponsors for energy and environmental science and technology include the Office of Science (DOE-SC), the Office of Energy Efficiency and Renewable Energy (DOE-EE), the Office of Fossil Energy (DOE-FE), and the Office of Nuclear Energy, Science and Technology (DOE-NE), as outlined in Sects. 5.1 and 5.2. Much of ORNL's work for other sponsors (see Sect. 5.6), such as the Nuclear Regulatory Commission (NRC) and the U.S. Department of Transportation, is also directed toward the solution of energy-related problems. Partnerships with other national laboratories, other federal agencies, state governments, and industry (see Sect. 6) contribute to ORNL's extensive foundation of expertise in energy and environmental science and technology. Complementing this foundation are diverse resources in analytical methods and engineering.

The E²SF Initiative will leverage the results of these efforts in working to understand and minimize the health and environmental consequences of energy production and use, improve the efficiency of existing energy systems, and develop new options for energy services. The integration of economic and environmental analyses into the development of energy technologies at ORNL will add value to individual technology-specific programs by providing a perspective on market potentials, environmental implications, and other factors related to the success of longer term technology R&D.

Energy Science and Technology

ORNL's capabilities and expertise are applied to a diversity of tasks in energy production, energy storage, and energy efficiency, as outlined in Sect. 5.2. Several specific R&D programs are of particular importance to the development of clean energy systems.

Nuclear Energy. Nuclear energy represents an important element of an integrated clean energy supply strategy, and ORNL's long-term involvement in nuclear technology and safety has provided the Laboratory with distinctive capabilities and facilities for the R&D needed to support this energy option. Current R&D activities (see Sect. 5.2.3) include work aimed at extending the life of currently operating reactors, developing and defining technology for advanced "Generation IV" reactors, developing enabling technology to lower the cost of future generations of nuclear power plants, and basic research on fuels and high-temperature irradiated materials. ORNL is also working to ensure acceptable levels of safety for nuclear power plants.

Fossil Energy. The ORNL Fossil Energy Program (see Sect. 5.2.2) embodies a broad range of research, including advanced structural and functional materials, bioprocessing, combustion, carbon sequestration, gas production and utilization, and oil production and environmental technologies.

Expanding programs in fuel cells and functional materials; carbon sequestration; and methane hydrates offer will be important to the E²SF Initiative.

Energy Efficiency and Renewable Energy. ORNL's capabilities and expertise are applied to a diversity of tasks in energy efficiency and renewable energy for DOE-EE, as described in Sect. 5.2.1. Strengths in building technologies, distributed energy systems, and transportation are particularly applicable to the E²SF Initiative. ORNL will work to expand these strengths through the development of new facilities, capabilities, and partnerships. Resources will include:

- construction of a new Energy Efficiency Research Laboratory (see Sect. 4.4.4.3) and the Advanced Materials Characterization Laboratory (see Sect. 4.5.2),
- a growing program in carbon composites research, and
- partnerships drawing on the capabilities of the National Transportation Research Center.

Laboratory resources in hybrid systems, advanced engines, emissions, power electronics and electric machinery, and materials technologies support the development of clean, efficient, and affordable transportation systems, addressing the goals of the E²SF Initiative.

Fusion Energy. In the longer term, fusion energy could be an attractive element of the global energy system. Fusion produces no carbon emissions, and its basic fuels, deuterium and lithium, are abundant and widely available. As a complement to fission energy, fusion offers potential safety advantages deriving from the low stored energy of fusion power systems, the minimal risk of proliferation, and substantially smaller volumes of radioactive wastes from the fusion fuel cycle. ORNL manages a broadly based fusion energy sciences program (see Sect. 5.1.4) that supports DOE's aim of demonstrating fusion's potential to be an economical, environmentally acceptable energy source.

Global Climate Science and Carbon Management

With growing evidence that energy-related actions are giving rise both to global warming and to increased variation in climate and weather, the ability to understand and predict changes in global climate is critical to future decisions about energy. Climate prediction with acceptable levels of uncertainty is one of the major goals of DOE's climate research efforts.

As part of the Climate Change Technology Initiative, the DOE-SC Office of Biological and Environmental Research (OBER) is undertaking several initiatives to understand the causes and effects of climate variability and climate change and climate prediction. In addition, the risk of global climate change from greenhouse gas emissions, of which the most important component is carbon dioxide from combustion of fossil fuels, has triggered efforts to understand the effects of atmospheric carbon dioxide concentrations and develop acceptable options for carbon management, including carbon sequestration.

ORNL strongly supports these initiatives and is developing a broad program in global climate change science and technology to assist DOE in determining appropriate responses to national climate change issues (see Sect. 5.1.2). This work includes the development of a comprehensive carbon management R&D program to analyze, evaluate, and understand opportunities to reduce carbon dioxide emissions. This program is focused on the following tasks.

- Grow carbon sequestration R&D through internal investments in and programmatic support of advanced chemical, biological, and engineering technologies, capitalizing on existing DOE support to understand the potential for carbon sequestration in terrestrial ecosystems, the oceans, geologic formations, and investigate advanced concepts in chemical and biological systems.
- Strengthen research and analytical capabilities for evaluating carbon management options through new terrestrial ecosystem facilities and modeling studies.

Complementing these tasks are expanded efforts in energy efficiency R&D (focusing on building technologies, distributed power systems of combined heat and power, and transportation), which would reduce carbon emissions by reducing the total amount of energy used, and clean power R&D (addressing fuel cells, gas turbines, and reciprocating engines; hydrogen production and storage; methane hydrates; and the genetic basis for agricultural biomass), which would reduce carbon emissions by reducing the carbon intensity of energy generation.

ORNL's carbon sequestration R&D portfolio comprises interdisciplinary efforts supporting several DOE offices. Within DOE-SC, OBER is funding efforts that include use of the Seafloor Process Simulator facility to investigate methods of lowering the cost and reducing environmental impacts of directly injecting CO_2 into the deep ocean. Research on the terrestrial option ranges from the molecular and genetic controls on carbon in vegetation and soil to global-scale assessment of strategies to reduce greenhouse gas emissions. Recognizing the importance of faster, more accurate measurements of carbon in soils, ORNL is developing new instruments that may make this capability available for extensive use at a global scale. With funding from DOE-FE, scientists are exploring the use of fossil fuel by-products to enhance carbon sequestration during the reclamation of degraded lands; this project will also take an aggressive approach to transferring new science into industrial partnerships. New biological processing options supported by DOE-FE may aid in this area as well. ORNL's historical strength in materials and separation sciences are being used to develop technologies that may lower the cost of separating and capturing CO_2 from point sources such as fossil fuel energy plants. ORNL scientists are also involved in the GEO-SEQ, a public-private consortium supported by DOE-FE that is studying ways of optimizing subsurface geologic formations for storing CO_2. Fundamental research on fluid-rock interactions, funded by DOE-SC's Office of Basic Energy Sciences, may help to resolve key uncertainties.

Analytical Methods and Engineering

In addition to providing a focal point for most of ORNL's energy and environmental R&D activities, the E²SF Initiative will engage Laboratory resources in determining the economic and environmental consequences of energy choices.

ORNL will bring to bear its unique resources for developing and applying the tools and techniques needed to determine the social, economic, environmental, and security consequences of particular choices of energy technologies. These tools and techniques will support the selection of policies that will be most effective in bringing about a sustainable energy future. We will continue to apply Laboratory expertise in the natural sciences, economics, and social science to environmental impact assessments and to the development of ecological and regional-scale risk analysis, regional and global-scale modeling, uncertainty analysis, and radiological hazard assessments.

ORNL also has unique resources for developing and applying assessment and prediction tools and techniques. Ongoing activities include applied research and integrated assessments of the engineering, environmental, and social impacts of a broad range of energy-related activities, drawing on expertise in the natural, social, engineering, and computational sciences and in technology development. The following are key resources for the E²SF initiative.

Integrated Assessment. Binding together ORNL's rich technical strengths in the development of clean energy systems is a widely recognized capability to carry out innovative, independent, integrated assessments that span energy, economics, and the environment. In recent years, the Laboratory has been actively involved in a host of national and international energy, economic, and environmental integrated assessments, both learning from and contributing to the collective body of knowledge and experience. For example, ORNL co-led an interlaboratory working group commissioned by DOE to examine the potential for public policies and programs to foster clean and efficient energy technology solutions to a variety of energy-related challenges.[5] Two current LDRD projects are aimed at expanding the science base for integrated assessments of carbon management issues.

Measurement Sciences. ORNL's expertise in measurement sciences provides important enabling technologies to meet E²SF goals. For example, systems being developed for the DOE-NE Nuclear Energy Research Initiative enhance controls strategies for advanced nuclear reactors. ORNL is also developing and using advanced diagnostics to assess the operation of nuclear plants, to ensure that the original design requirements are continuously met over the lifetime of the plant.

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[5]Interlaboratory Working Group, *Scenarios for a Clean Energy Future*, ORNL/CON-476, UT-Battelle, LLC, Oak Ridge, Tenn., and LBNL-44029, University of California, Berkeley, Calif., November 2000.

ORNL is developing a wide variety of "smart sensors" that merge sensitive detection abilities with computing and signal transmission capabilities. These devices support detection, monitoring, and tracking of environmental contaminants; prediction of the effects of climate change; improvements in measurement and inspection techniques that enhance the efficiency and competitiveness of manufacturing; and a host of other applications.

Robotics and Intelligent Machines. ORNL's cross-cutting capabilities in robotics and intelligent machines (RIM; see Sect. 5.3) are a notable resource for the E²SF Initiative. The need for operational efficiency improvements and worker protection in advanced nuclear fission and fusion energy production facilities will mandate the widespread application of RIM technologies in these facilities. RIM technologies can also be used to reduce or eliminate worker hazards unique to fossil energy resource exploration, resource extraction, and production operations. Advances in manufacturing and production technologies founded on RIM research will reduce the cost of producing renewable energy technologies. RIM research will also play a role in enabling new avenues of energy production and distribution that are both efficient and safe for the worker and the environment.

Separation Sciences. Increasing the efficiency of separations processes in the most energy-intensive industries and developing separations processes for clean energy production will be among the keys to a sustainable energy future. As DOE's principal laboratory for chemical separations and analysis,[6] ORNL plays a leading role in the development of novel energy-efficient separations and energy-related processes. The ORNL Center for Separations and Chemical Processing (see Sect. 5.2.3) integrates fundamental separations research with capabilities in characterization and measurement, terascale computing, materials development, and sensors and controls for development of advanced energy technologies.

4.4.4.2 • Securing New Capabilities

Innovative research that supports the goals of the E²SF Initiative has been identified as a target area for ORNL's Laboratory Directed R&D (LDRD) funds (see Sect. 5.7). In FY 2002, ORNL will invest in building a strong R&D portfolio in five R&D topic areas.

- **Energy efficiency:** R&D that advances and increases energy efficiency through more efficient use of electricity, industrial resource recovery and use and more efficient industrial processes, and increased transportation efficiency.
- **Clean power:** R&D that accelerates the implementation and use of energy sources with lower or no emissions, such as nuclear, biomass, and ultra-low-emission transportation systems.
- **Carbon sequestration:** R&D that advances the understanding of carbon sequestration potential or increases the efficiency of separating carbon from other gases.
- **Measurement sciences:** New measuring systems that can be integrated with new energy production and energy conservation technologies and that significantly advance the state of the art in measurement science for understanding and controlling energy systems of the future.
- **Integrated assessment:** R&D that assesses environmental, economic, and social trade-offs of new energy technologies and evaluates alternative future energy systems, taking into account both near-term policy priorities and longer term strategies for the nation.

4.4.4.3 • Developing Experimental Facilities

New research facilities will be required to advance the understanding of key energy development issues. ORNL is planning four facilities that support the broad research agenda of E²SF.

Terrestrial Ecosystems Research Facility

As described in Sect. 5.1.2, ORNL will work with other national laboratories and the university community to integrate expertise in ecosystem research, the carbon cycle, carbon sequestration, environmental sciences, ecological process studies, landscape ecology, and global carbon science with capabilities

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[6]Laboratory Operations Board, *Strategic Laboratory Missions Plan—Phase I*, Vol. II: *Mission Activity Profiles*, U.S. Department of Energy, Washington, D.C., July 1996, p. SC-10.

for measurement, modeling, and monitoring of the environment to define and create new approaches to ecosystem research. Leveraging and enhancing current assets in large-scale ecosystem manipulation, integrated data management, ecological modeling, measurement science and sensor development, and computational science will provide capabilities to improve the understanding of large-scale environmental processes and the response of ecosystems to energy-related stresses.

A critical component of this new thrust will be the ability to address the effects of multiple factors (e.g., temperature and carbon dioxide) and determine the effects of multiple stresses on ecosystems. A better understanding of environmental processes at multiple scales of resolution is critical to addressing the issues associated with developing clean energy systems. In FY 2000, ORNL and Brookhaven National Laboratory brought together representatives of 7 DOE national laboratories and 16 universities to develop a science-driven requirements document for the development of one or more large-scale terrestrial ecosystems research facilities. This report, *Terrestrial Ecosystems Research Facility: Advancing Terrestrial Ecosystem Science*, will serve as the basis for development of a comprehensive program plan for evaluation by DOE.

Energy Efficiency Research Laboratory

As described in Sect. 5.2.1, ORNL is proposing the Energy Efficiency Research Laboratory as a line item for project engineering and design in FY 2003 and for construction in FY 2004 and FY 2005. This facility will support the missions and goals of three program areas that are key to the E²SF Initiative: distributed energy resources, high-temperature superconductivity, and buildings research. The strategic importance of these research areas is highlighted in the 2001 *National Energy Policy* report. The facility will also enable ORNL to move into emerging research areas such as new cooling, heating, and power delivery strategies linked to electricity reliability and power quality.

Bioenergy and Carbon Sequestration Systems

The Oak Ridge Reservation Bioenergy and Carbon Sequestration Systems activity (see Sect. 5.2.1) will use the Oak Ridge Reservation, including the ORNL campus, to create an integrated testbed for research and demonstration of terrestrial carbon sequestration technologies and bioenergy and bio-product systems and their impacts. It will provide opportunities for full-system research and analysis of both bioenergy and carbon sequestration technologies, including economic and environmental impacts.

We envision the manipulation of ecosystems at the watershed scale to test carbon sequestration technologies and the creation of multiple-hectare stands of energy crops to support the development and testing of harvesting technologies and the evaluation of environmental and economic features of bioenergy systems. These manipulated watersheds and energy crop fields will serve as "facilities" both for ORNL and for outside researchers, much as the Oak Ridge National Environmental Research Park now functions as a user facility. The implementation of bioenergy as a component of the energy mix at the west end of the ORNL campus will likewise provide a "facility" for research on the economics and logistics of bioenergy systems.

Quasi-Poloidal Stellarator

As described in Sect. 5.1.4, ORNL is proposing the Quasi-Poloidal Stellarator (QPS) experiment to (1) obtain new physics results on confinement of plasmas in an innovative magnetic confinement geometry and (2) explore the potential of this compact variant of the stellarator approach as a more attractive fusion power reactor. Physics results from the QPS will complement those from other experiments and broaden the understanding of toroidal confinement, a main theme of the U.S. fusion program. In the long term, the QPS approach could lead to an attractive fusion reactor that combines the best features of stellarators and tokamaks.

4.4.4.4 • Building Strategic Partnerships

The E²SF Initiative will create integrated solutions for addressing global energy needs, bringing together "best-in-class" expertise in partnerships that span disciplines and institutions. Most of ORNL's

divisions and programs will play key roles in developing E²SF. In East Tennessee, the National Transportation Research Center links the transportation programs at ORNL and the University of Tennessee (UT), presenting opportunities to develop integrated solutions for management of emissions associated with transportation, and the Joint Institute for Energy and Environment focuses the resources of ORNL, the Tennessee Valley Authority, and UT on finding solutions to key national and international issues of energy, economics, and the environment. ORNL is partnering with Sandia National Laboratories to evaluate and propose an advanced nuclear reactor (see Sect. 5.2.3). The four DOE laboratories managed by Battelle businesses—ORNL, Brookhaven National Laboratory, Pacific Northwest National Laboratory and the National Renewable Energy Laboratory—are linking their resources in the Battelle-DOE Carbon Management Network. The planned DOE Multilaboratory Regional Climate Network will contribute to the understanding of carbon dynamics. Other partnerships that will be involved include the ORNL-NREL National Bioenergy Center; CSiTE; the GEO-SEQ team; the Oak Ridge Center for Advanced Studies (see Sect. 6.2), and the planned Terrestrial Ecology Research Facility. Science education programs will promote both a broader awareness of the problems to be solved and the development of skills for solving them in a new generation of scientists and engineers.

4.5 • Advanced Materials

Our Advanced Materials Initiative is aimed at sustaining ORNL's position as a world-class advanced materials R&D laboratory supporting DOE's missions. This initiative includes the development of a recognized capability in nanoscale science, engineering, and technology; the establishment of the Center for Nanophase Materials Sciences; the construction of the Advanced Materials Characterization Laboratory; and the development of extraordinary tools for materials characterization and the extension of ORNL's capabilities for synthesis and processing.

4.5.1 • Nanoscale Science and Engineering

A key aspect of the Advanced Materials Initiative is the development of a program, supported by an investment of Laboratory Directed R&D (LDRD) funds (see Sect. 5.7), in nanoscale science, engineering, and technology (NSET). This program supports the Department's continuing efforts to advance the fundamental understanding of nanoscale phenomena through experiment, theory, and simulation; to develop new methods for predicting these phenomena; and to extend the ability to design, synthesize, and characterize materials at the atomic level, leading to new and enhanced functionality.

Nanoscience is concerned with discovering, understanding, characterizing, and fabricating materials and systems with novel properties, phenomena, and processes that occur primarily because of their small size. Structures having dimensions of 1 to 100 nm (10^{-9} to 10^{-7} m) can induce important property changes that go well beyond those of their isolated component molecules (~1 nm). Additionally, properties induced by such structures may not be predictable from those exhibited by larger structures. New behaviors associated with the nanoscale are not merely the result of orders-of-magnitude reduction in size, but are caused by the emergence of entirely new phenomena. These include the effects of confinement on electronic structure, the dominance of interfacial and surface phenomena (in contrast to bulk effects) with increasing surface-to-volume ratio, and quantum effects. Consequently, modeling and simulation play an important role, complementing experimental discovery, in developing a full and fundamental understanding of these effects.

Nanoengineering and nanotechnology are concerned with developing structures and systems that use and enhance the significantly improved properties of their nanoscale components. By learning how to control feature size and to assemble appropriate "building blocks," it should be possible to enhance the properties of materials and to create functional devices with greatly improved or entirely new functions. This goal, however, requires both discovering the underlying principles and developing the tools needed to apply them systematically.

In recognition of the critical importance of this emerging field, Congress provided an increase of $227 million for research in NSET in FY 2001. The multiagency National Nanotechnology Initiative (NNI) will strengthen scientific disciplines and create critical interdisciplinary opportunities. It is expected to lead to breakthroughs in numerous fields, many of them central to DOE's missions, including materials, manufacturing, energy, environmental quality, information technology, and national security.

DOE is one of six agencies participating in the NNI. Its portion of the FY 2001 increase in NSET investment is $36 million. The NNI will build on DOE's unique capabilities for visualizing, characterizing, and controlling matter at the nanoscale and on a broad portfolio of R&D already under way at the Department's laboratories. DOE resources include a diverse array of national user facilities, with unique capabilities for investigation of nanoscale materials and processes, and computational facilities to support the modeling and simulation needed in developing a comprehensive understanding of the nanoworld.

For FY 2002, NSET has again been identified as a target area for ORNL's LDRD funds (see Sect. 5.7). A one-day workshop on NSET-related R&D was held at ORNL on May 15, 2001, to communicate ORNL progress and opportunities in NSET to Laboratory staff. Nobel Laureate Richard Smalley was the keynote speaker for this event.

The NSET component of the Advanced Materials Initiative will position ORNL for the science and technology of the future, building on (1) a strong core materials science and engineering program, (2) a variety of capabilities and expertise to synthesize new materials and to process them into nanoscale configurations molecule by molecule, (3) world-class characterization facilities that can "see" new materials configurations at the atomic level and determine their properties, and (4) high-performance computer modeling and simulation capabilities to understand materials properties and predict new configurations.

4.5.2 • Center for Nanophase Materials Sciences

The Center for Nanophase Materials Sciences will be a national facility for advancing the understanding of nanoscale phenomena in materials. It will leverage the unprecedented opportunity for new research on the structure and dynamics of nanoscale materials systems that will be afforded by the SNS and the upgraded HFIR. The focus will be on interdisciplinary research areas that benefit from access to neutron scattering, including soft materials, interfaces, nanoscale magnetism, and other nanophase systems. Research will provide the foundation for new nanotechnologies based on these materials systems and will optimize the use of the SNS and the upgraded HFIR for nanoscience-related research.

Working through university and industry partnerships, the Center for Nanophase Materials Sciences will create an environment and provide facilities for rapid progress in interdisciplinary nanoscale science and engineering. It will also provide training for graduate students and postdoctoral associates in interdisciplinary nanoscale science with particular emphasis on nanoscale materials synthesis and characterization, assembly of nanomaterials systems, and fundamental understanding of nanoscale phenomena.

The Center for Nanophase Materials Sciences was approved by BES in FY 2001 and has been proposed as a line item construction project beginning in FY 2002 (see Table 4.6). It will be housed in a 7,430-m^2 (80,000-ft^2) laboratory/office complex to be constructed adjacent to the SNS and the Joint Institute for Neutron Sciences. This facility will include clean rooms and specialized equipment for nanoscience research that cannot be accommodated in existing space at ORNL.

The Center for Nanophase Materials Sciences responds to the recommendations of *Nanoscale Science, Engineering, and Technology Research Directions*, a 1999 report prepared by members of the Office of Basic Energy Sciences Nanoscience/Nanotechnology Group, and will provide a unique national resource in the nanosciences. Preliminary design activities for the facility were initiated in FY 2001. A workshop to facilitate community involvement in the planning for the Center, held in October 2001, was attended by 270 participants from 67 institutions.

Table 4.6
Funding profile for the Center for Nanophase Materials Sciences
by fiscal year
(project engineering and design and construction)

FY 2002	FY 2003	FY 2004	FY 2005	Total
$1,500,000	$25,000,000	$20,000,000	$17,250,000	$63,750,000

4.5.3 • Advanced Materials Characterization Laboratory

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

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

ORNL will construct an Advanced Materials Characterization Laboratory (AMCL) to address this issue. A new structure with 1,115 m^2 (12,000 ft^2) of space, the AMCL will provide the high-quality environment required to optimize the performance of sophisticated characterization equipment essential for the next generation of advanced materials R&D. The AMCL is included in ORNL's Facilities Modernization Initiative (see Sect. 7.3.3.1) as a General Plant Project (GPP) budget item with a cost of $4.0 million, to be completed in FY 2003.

The AMCL will foster state-of-the-art materials characterization that is essential for understanding materials and materials-related processes and phenomena that underpin energy technologies and industrial endeavors. Specifically, the facility will house equipment funded by several DOE offices, primarily the Office of Science (DOE-SC) and the Office of Energy Efficiency and Renewable Energy (DOE-EE). Two of ORNL's major user programs—the High Temperature Materials Laboratory, funded by DOE-EE, and the Shared Research Equipment Collaborative Research Center, funded by DOE-SC—include a strong emphasis on electron-beam characterization and related techniques that will be supported by this facility.

4.5.4 • Extraordinary Tools for Materials Characterization

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

The Spallation Neutron Source (SNS) and the upgrades to the High Flux Isotope Reactor (HFIR) and associated neutron scattering facilities (see Sect. 4.1) will provide the world's best capabilities for probing materials with neutrons. ORNL's investment of LDRD funds in several key areas of neutron science (see Sect. 5.7) is supporting the development of new tools, including novel instrumentation, advanced neutron optics, and data visualization and analysis, for utilizing these capabilities.

The need for advanced X-ray characterization tools is being addressed by the development of beam lines on the Advanced Photon Source (APS) at the Argonne National Laboratory. Microbeam capabilities are extending the understanding of materials phenomena to mesoscale length scales, elucidating key materials problems such as stress-driven grain growth, aging, and materials failure. ORNL

is developing a dedicated microbeam facility directed toward 0.1-μm resolution in collaboration with the University of Illinois, the National Institute of Standards and Technology (NIST), and UOP Research Inc. Funding provided through the DOE-SC Office of Basic Energy Sciences is being applied to develop a mesoscale materials program using microbeams at the APS.

Future needs for electron characterization and related techniques will be supported by construction of the AMCL, as described in Sect. 4.5.3, and by continuing efforts to expand ORNL's resources for high-resolution characterization of the microstructure and microchemistry of materials, with the goal of acquiring the world's highest resolution electron microscopes. Key areas of expertise include

- analytical electron microscopy, including high-resolution imaging, convergent-beam electron diffraction, electron energy-loss spectroscopy (EELS), energy-dispersive X-ray spectroscopy, spectrum imaging, and energy-filtered imaging;
- atomic-resolution scanning transmission electron microscopy (STEM), including *Z*-contrast imaging and atomic-resolution EELS;
- atom probe field-ion microscopy, including atomic-resolution imaging, high-resolution time-of-flight spectroscopy with single-atom sensitivity, and three-dimensional atom probe techniques;
- analytical scanning electron microscopy, including secondary and backscattered electron imaging, energy-dispersive and wavelength-dispersive X-ray microanalysis, and electron backscattered pattern orientation measurements; and
- mechanical properties characterization with submicrometer spatial resolution, including nanoindentation experiments at ambient and elevated temperatures; hardness, modulus, viscoelasticity, creep, scratch, and fracture toughness measurements; and atomic force microscopy.

A new aberration-corrected transmission electron microscope, funded by DOE-EE and scheduled for delivery in FY 2003, will contribute to the needed expansion of ORNL's resources. In addition, DOE-SC is providing support to upgrade ORNL's STEM facilities to sub-angstrom resolution.

4.6 • National Security

The thrust of our new initiative in national security is to maintain and expand ORNL's position as a leader in the development of science and technology to solve the security and public safety challenges faced by federal, state, and local governments and the industries that build systems and components for these agencies. The elements of this initiative are designed to focus the distinctive capabilities of the Oak Ridge Complex on specific opportunities, leveraging the science and technology developed to meet DOE's needs and broadening the customer base for security-related technologies and expertise. The ORNL National Security Directorate will take the lead in this initiative, but nearly all Laboratory organizations are expected to participate in it at some level.

Focus areas include counterterrorism; nonproliferation of weapons of mass destruction (WMD) or mass effect (WME); combating asymmetric warfare or nontraditional threats to U.S. homeland security; law enforcement, public safety, and emergency management; logistics applications; and specialized training for military personnel.

ORNL will work with DOE, the Department of Defense (DOD), and other federal agencies with national security missions to find more cost-effective means of developing and deploying security-related technologies, with an emphasis on eliminating redundancy, increasing efficiency, and delivering value. ORNL will also seek to review possibilities with past customers, expand its work with present customers, and find opportunities with new customers by matching Laboratory technologies and expertise to needs. New partnerships with industries and universities that supply science and technology innovations to national security organizations will be developed.

4.6.1 • Technologies for Counterterrorism and for Detection/Defeat of Nuclear, Chemical, and Biological Weapons

Materials and substances that can cause widespread destruction and loss of human life are becoming easier to obtain through a variety of means, both legal and illegal. ORNL is engaged in R&D and engineering of technologies to better detect, locate, identify, characterize, and attribute the proliferation of WMD through measurement and analysis of signatures gathered at close range by low-profile sensing and analysis devices and at long range by increasing the sensitivity and understanding of more traditional techniques. The key components required to successfully achieve the goals of this activity include radiation detection technologies, microtechnologies, nuclear materials analysis and forensics, and detection and defeat of chemical and biological agents.

To expand its role in developing counterterrorism and chemical/biological detection technologies, the Laboratory will establish a program in FY 2002 to engage ORNL directorates and divisions in an active partnership with Y-12's National Security Program Office. The initial focus will be on two substantial technology needs that can be met by ORNL competencies: biological warfare agent detection standards and a forensics capability to support investigation and prosecution of terrorists involved in chemical and biological attacks. Also envisioned is the development of small portable power supplies to support DOD, the intelligence community, and law enforcement organizations in their efforts to combat terrorism.

4.6.2 • Asymmetric Warfare Technologies

Since the United States currently has no peer military force-on-force competitor, future foes can be expected to challenge this country through the use of asymmetric, or "David-and-Goliath," approaches. These foes will seek to avoid direct attacks on U.S. strengths and concentrate instead on indirect methods and techniques to attack perceived vulnerabilities. In some instances, this could mean using WMD or weapons of mass effects WME against the U.S. homeland; in others, it could mean disrupting the information or electronic systems on which the United States is increasingly dependent.

This challenge is difficult both to recognize and to combat, and science and technology will play an important role in defending the United States against this form of warfare. Focuses for this activity include working with the appropriate government agencies in detecting, monitoring, disarming, and recycling WMD; anticipating the types of nonlethal warfare systems (e.g., incapacitants) that foes will use and finding countermeasures to them; developing data mining and other pattern detecting capabilities to deter or protect against data/image manipulation; and creating technologies that organize and present data, information, or knowledge in ways that enable decision-makers to make better and faster decisions than an asymmetric opponent.

4.6.3 • Technologies for Law Enforcement, Public Safety, and Emergency Management

Building on a record of demonstrated success in support for law enforcement and public safety, ORNL is establishing a Public Safety Technology Alliance that will promote safe and secure communities by applying advanced technology developed in Oak Ridge to assist communities with technological solutions to challenging public safety problems. Potential alliance partners include the Law Enforcement Innovation Center (LEIC), state bureaus of investigation, the National Institute of Justice, and selected DOE programs [the Office of Nonproliferation Research and Engineering (NN-20), the Special Technologies Program, etc.].

The LEIC was created in FY 2000 by a federal grant to the Knoxville (Tennessee) Police Department and the University of Tennessee with the vision of becoming the premier center for innovative law enforcement to serve city, county, and state law enforcement organizations. The center's goal is to foster innovations in law enforcement–related technologies, forensic R&D, and other areas related to law enforcement and community quality of life. ORNL supports the LEIC by providing a qualified executive

to run the program. Activities include the National Forensic Academy, an intensive, 10-week training program beginning in September 2001.

4.6.4 • Technology for Logistics Applications

ORNL is studying ways to apply science and technology to the logistical challenges currently confronting both military and commercial organizations. One such effort is in total asset visibility for hazardous materials (HAZMAT) tracking. Efforts to develop Advanced HAZMAT Rapid Identification, Sorting, and Tracking (AHRIST) will determine whether advanced identification technology and automatic data collection can be used to solve ongoing problems with the identification of HAZMAT at DOD logistics depots. Similarly, logistics management initiatives will improve DOD's logistics practices by ensuring a fully integrated supply chain, streamlined business processes, and identification of best-value competitive logistics providers.

ORNL will also participate in advanced technology demonstrations with a particular focus on partnering with commercial industries with detailed knowledge of commercial logistics processes that have value to DOD. Finally, ORNL's transportation modeling and simulation capabilities provide new approaches for information technology R&D that focus on strategic transportation requirements, analysis, and collaborative decision-making. All of these technology tools, once developed, are available for use by transportation/commercial industries.

4.6.5 • Training With Industry Program

ORNL is undertaking the training and education of the U.S. Army's future leaders by participating in the service's Training With Industry (TWI) Program. This program was established to train selected officers in disciplines, programs, and technologies that are important for the Army to understand but that the Army cannot cost-effectively address on its own because of the small number of personnel involved. The value of this program, and ORNL's importance to it, is the relationship between technology and the Army's efforts to transform itself from what it is today to the capabilities it will need by the year 2020.

The centerpiece of this transformation is the use of science and technology to design, prototype, build, and deploy the machines and systems that will be used by soldiers in the future. To ensure that it makes the right decisions for the long term, the Army has elected to develop a cadre of officers who have been educated on scientific processes and methodology, who understand the challenges of designing new technologies, and who have a thorough grasp of where to turn for answers once they leave the program and rejoin the Army. Each individual spends 10 months in training; the program will be an ongoing collaboration between the Army and ORNL. The U.S. Marine Corps is also interested in developing a similar program with ORNL.

5 • Program Descriptions and Directions

As a multiprogram national laboratory, the Oak Ridge National Laboratory (ORNL) carries out research and development (R&D) in support of all four major missions of the Department of Energy (DOE): science, energy resources, environmental quality, and national nuclear security. 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 but can and do lead to productive new technical directions.

Our commitment to excellence in science and technology, reflected in the Laboratory Agenda (see Sect. 3.2), includes the delivery of scientific advances and technological innovations in support of DOE's missions through the R&D programs described in this section. Table 5.1 outlines some specific program directions and their connections to DOE mission areas.

Table 5.1
Relevance of ORNL program directions to DOE missions

	DOE mission area			
Activity	Science	Energy Resources	Environmental Quality	National Nuclear Security
Biomedical Engineering and Bioengineering	S	S	S	M
Large-Scale Environmental Process and Effects Research	S	S	S	
Carbon Sequestration Research	S	S		
Quasi-Poloidal Stellarator	S	S		
Nuclear Physics with Radioactive Ion Beams	S			
Energy Efficiency R&D Facility	M	S		
Distributed Energy Resources		S		
Carbon Composites Research for Transportation	M	S		
Oak Ridge Reservation Bioenergy and Carbon Sequestration Systems	M	S		
Separations Science and Chemical Processing	S	S	S	M

S = Strongly supportive.
M = Moderately supportive.

5.1 • Science

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

5.1.1 • Basic Energy Sciences—KC

The DOE-SC Office of Basic Energy Sciences (BES) supports a broad spectrum of research in the physical sciences at ORNL through its subprograms in materials sciences, chemical sciences, and engineering and geosciences. Major ORNL endeavors supported by BES include the Spallation Neutron Source (SNS) and the High Flux Isotope Reactor (HFIR) upgrades, which are discussed in Sect. 4.1. ORNL's Advanced Materials Initiative (see Sect. 4.5) also draws on BES support.

The BES **Materials Sciences** subprogram supports a comprehensive fundamental materials R&D effort in support of DOE's missions. An integrated, interdisciplinary approach is emphasized, including major research efforts in neutron scattering; synthesis, processing, and characterization of advanced materials; high-temperature materials; soft materials; superconductivity; surfaces, interfaces, and thin films; synchrotron research; electron beam microcharacterization; ion beam and laser processing; and theoretical studies. The program benefits from access to unique, state-of-the-art materials research facilities and from close interactions with materials-related energy technology programs. Major research initiatives comprise the SNS and the neutron scattering upgrades at HFIR (both described in Sect. 4.1) and the Advanced Materials Initiative (see Sect. 4.5), which includes the construction of the Center for Nanophase Materials Sciences and the Advanced Materials Characterization Laboratory at ORNL and the development of synchrotron beam lines at the Advanced Photon Source at the Argonne National Laboratory.

The Materials Sciences subprogram operates one national user facility, the HFIR, and two national collaborative research centers: the Surface Modification and Characterization Collaborative Research Center (SMAC) and the Shared Research Equipment Collaborative Research Center (SHaRE). In addition, through the Oak Ridge Institute for Science and Education (ORISE), BES supports the Oak Ridge Synchrotron Organization for Advanced Research (ORSOAR) for access to the ORNL beam lines on the Advanced Photon Source. These facilities provide specialized research capabilities to hundreds of research scientists and graduate students from universities, industry, and government laboratories.

ORNL is a leader in fundamental materials science and in the development of advanced materials, processes, and characterization technologies. New capabilities will extend ORNL's contributions in these areas. The SNS and the HFIR upgrades are addressing a long-term national need for improved neutron science facilities and will provide outstanding opportunities in many fields. The Advanced Materials Initiative will foster the development of new facilities, tools, and capabilities. New research directions include ultrahigh-temperature intermetallics, ceramic surfaces and interfaces, soft materials, and the effects of reduced dimensionality and nanoscale geometries on materials properties.

The Materials Sciences subprogram also advances the understanding of materials and materials-related phenomena that underpin energy technologies. Basic research in materials sciences is integrated with the R&D efforts of DOE's applied programs, especially the materials-related efforts funded by the DOE Office of Energy Efficiency and Renewable Energy, the DOE Office of Fossil Energy, and the fusion energy sciences program in DOE-SC. Key endeavors that benefit from materials R&D include the Industries of the Future initiative and environmental technology development programs.

The BES **Chemical Sciences** subprogram supports the operation of the HFIR/Radiochemical Engineering Development Center (REDC) complex. The HFIR, which provides the highest steady-state flux of thermal neutrons in the world, is used for neutron scattering R&D, the production of isotopes, materials irradiation, and neutron activation analysis. Neutrons from the HFIR are vital to research in the materials sciences, chemical sciences, magnetic fusion, and life sciences programs at ORNL and for external users and collaborators. Each year approximately 400 researchers use its facilities. Activities at the REDC involve the development and use of production processes and product forms for radioisotopes, predominantly the isotopes of transuranium elements; the production of portable neutron sources using ^{252}Cf for applications in industry, medicine, and national security; and the operation of the Californium User Facility for Neutron Sciences.

The Chemical Sciences subprogram also supports programs in molecular processes, which feature particular strengths in mass spectrometry, properties of high-temperature aqueous electrolyte solutions, separations chemistry and chemical engineering, organic chemistry of energy resources, actinide science, and hydrothermal and isotopic geochemistry. Current research emphases include improving the understanding of chemical conversions that underpin new or existing concepts for energy utilization and conversion; exploring the chemistry and physics required to conceptualize new analytical methods; using molecular recognition concepts to design selective separations involving solvent extraction; developing a greater understanding of complex phenomena involved in multiphase separations; unraveling the systematics of the solid-state behavior of actinide elements and compounds; relating the thermodynamic

properties of aqueous solutions at extreme conditions to molecular structure; developing advanced battery concepts; and quantifying fundamental geochemical processes that control matter and energy transport.

The ORNL portfolio for the Chemical Sciences subprogram also includes a program incorporating experimental and theoretical research in atomic, molecular, and optical sciences. This work is aimed at understanding, and ultimately controlling, matter on the atomic scale through the investigation of the interaction of atomic particles scattering from solid surfaces or penetrating matter. The program studies the basic physical and chemical processes occurring in atomic interactions and seeks the knowledge needed to purposefully manipulate surface/solid properties. Inelastic processes in plasmas, such as electron-atom/ion/molecule or ion-atom/molecule interactions, are studied because of their pervasive occurrence in a huge range of energy-relevant plasmas, such as those used in lighting, magnetic and inertial fusion energy, and technical plasma processing, again with the dual goals of fundamental understanding and robust control of the processes.

These investigations depend on the production of multicharged ions and the application of several highly advanced, unique experimental techniques to control and observe their interactions with other atomic-scale matter (surfaces, solids, photons, electrons, ions, atoms, molecules, and molecular ions), made possible through the resources of the Physics Division's Multicharged Ion Research Facility and the Holifield Radioactive Ion Beam Facility (see Sect. 5.1.5). Intimately coupled with the experimental programs, providing guidance and supporting existing lines of research, theoretical studies are focused on the development of new physical models based on novel mathematical and computational techniques. Together, theory and experiment continue the basic research needed to make new discoveries, support and drive energy-relevant applications, and pursue a pathway to exercising an extended ability to manipulate and control processes and states of atomic-scale matter.

The BES **Engineering and Geosciences** subprogram sponsors the Center for Engineering Science Advanced Research (CESAR). CESAR's primary mission is to develop, through innovative research, a core of excellence in the area of intelligent systems technology, supporting the needs of DOE and other customers (see Fig. 5.1). CESAR is a collaborative research facility providing access to state-of-the-art technology and equipment in a stimulating research environment. Results and technology advances are distributed through publications in the scientific literature, workshops on selected topics, and the development of prototype systems.

Figure 5.1
Cooperative robots at ORNL's Center for Engineering Science Advanced Research (CESAR). Teams of autonomous mobile robots cooperatively solve problems that cannot be addressed by single robots acting alone.

This subprogram also supports studies of a variety of fluid-rock interactions and related hydrothermal processes with implications for oil, gas, and geothermal resource formation and exploitation; contaminant migration and remediation, deep subsurface fluid-rock interactions, and a wide range of general geochemical and industrial processes. ORNL organized an October 2000 symposium, "From Atoms to Organisms (and Back): Rates and Mechanisms of Geochemical Processes," in support of DOE's Geosciences Research Program.

5.1.2 • Biological and Environmental Research—KP

The mission of the ORNL Biological and Environmental Research (BER) Program is to advance science and technology in order to understand

- complex biological systems, ranging from single cells to ecosystems;
- the relationships of these complex biological systems to human health and the environment; and

- the responses of the environment to regional and global change, environmental stresses, and resource use.

The ORNL BER Program comprises distinguishing capabilities in biological research, with a focus on genetics and molecular biology; ecological and environmental systems; and environmental quality (see Table 5.2). These capabilities will be keys to achieving the overarching goal of DOE's proposed Genomes to Life (GTL) Program: a fundamental, comprehensive, and systematic understanding of life, with a near-term emphasis on understanding the susceptibility of human and environmental systems to adverse consequences of energy production, development, and use. The breadth of these capabilities derives from ORNL's role as a multiprogram laboratory. Partnerships with other organizations, both internal and external to the Laboratory, represent another key resource of the BER Program.

Table 5.2
Distinguishing capabilities of the ORNL BER Program

Genes to Molecules	Ecological and Environmental Systems	Environmental Quality
	Functions and activities	
Mouse genetics and genomics	Ecosystem and global change science	Subsurface science
Mouse mutagenesis and phenotype screening	Environmental process science and technology	Bioremediation
Neutron structural biology	Microbial biogeochemistry and biotechnology	Robotics and process systems
Bioinformatics/computational sciences	Ecological management science and technology	Chemical separations
Mass spectrometry	Environmental data systems	Geochemistry
Atomic force microscopy and nanotechnology	Renewable resources R&D	*In situ* methods for measurement and monitoring
Plant and microbial physiology, genetics, and genomics		Biological monitoring and abatement
Dosimetry, toxicology, and risk analysis		Sensor development
Biosensor development		
	Facilities	
Mouse Genetics Research Facility[a]/Laboratory for Comparative and Functional Genomics	Oak Ridge Reservation/National Environmental Research Park[a]	Field-scale R&D test sites
	Walker Branch Watershed, Melton Branch Watershed	Lysimeters
Center for Structural Molecular Biology[a]	NABIR Field Research Center	NABIR Field Research Center
Center for Computational Sciences	Free Air Carbon Dioxide Enrichment facility	Robotics development laboratory
Mass spectrometry laboratories	Throughfall Displacement Experiment	UXO detection system
High Flux Isotope Reactor[a]	Seafloor Process Simulator	Hot cells
Spallation Neutron Source	Center for Computational Sciences	Bioprocessing Research Facility[a]
	Laser laboratory	
	Flux tower (NOAA)	

[a]Designated user facility.

The principal activities of the BER Program include

- determining gene function in human, other mammalian, plant, and microbial systems on a genome-wide scale, focusing on systems relevant to DOE's missions, and performing comparative analysis of genomes;
- advancing the understanding of structure–function relationships by examining the structure of proteins and protein complexes and making specialized tools for structural biology (small-angle neutron scattering, mass spectrometry, and computational biology) available to the research community;
- exploring the interactions of energy-related chemical and physical agents with living organisms and the environment, including their transport, transformations, and health and environmental effects and their ultimate consequences for humans and the environment, and developing the scientific understanding needed for effective bioremediation of metal and radionuclide contamination;
- investigating microbial processes to address environmental threats (e.g., from contamination and pathogens) and to harness the capabilities of microbial systems for biofuel production, environmental remediation, and other applications;
- understanding and predicting the dynamic response of ecosystems to global and regional change, environmental contamination, and resource management;
- creating and applying new methods to monitor, assess, and manage ecosystems and to detect and mitigate environmental stresses from global and regional change, contamination, and resource use;
- developing renewable energy systems, especially bioenergy, through R&D in plant genetics and biotechnology and assessment of resource utilization, environmental impacts, and economics;
- carrying out basic and applied research and technology development to foster the invention and refinement of advanced instrumentation that addresses issues in genomics and proteomics, biomedical engineering, environmental protection, forensics, and national security;
- designing and developing tissue-specific radiopharmaceuticals for disease diagnosis and therapy, contributing to DOE's Nuclear Medicine Program and other beneficial applications by leveraging with advances in molecular biology and other rapidly developing fields; and
- developing and applying computational tools and techniques to address fundamental questions in the life and environmental sciences and to provide information and analytical resources to the wider research community and the public.

During the planning period, the BER Program will continue and expand its work in these areas. The major Laboratory initiative in complex biological systems (see Sect. 4.2) focuses the resources of the ORNL BER Program on the emerging field of "systems biology." The major Laboratory initiative in energy and environmental systems of the future (see Sect. 4.4) also builds on these resources, which will provide a deeper understanding of large-scale environmental processes and global climate that will underpin decisions about energy services.

The following strategic directions have been selected:

- contributing to the emerging OBER Advanced Medical Instrumentation Program in key areas, including biomedical and medical telesensors, efficient laser-based diagnostic and therapeutic procedures, biocompatible materials, novel bioinstrumentation development, and large-scale biomedical systems modeling and simulation;
- securing new facilities for large-scale environmental process and effects research, in support of DOE's Terrestrial Ecosystems Research Facility effort; and
- providing a science-based understanding of the carbon cycle, carbon sequestration, and carbon management.

Near-term actions to be taken in support of program goals include the development of

- a computational biology capability that builds on the high-performance computing resources of the ORNL Center for Computational Sciences (see Sect. 4.3.1) and
- an improved understanding of water cycle dynamics to allow better prediction of the effects of global change on regional water resources through the development of a water cycle regional test bed.

5.1.2.1 • Life Sciences

Research in the life sciences addresses the understanding of complex biological systems and includes comparative and functional genomics (involving model systems such as the mouse, microbes, zebrafish, and plants), genetics, biochemistry, biophysics, toxicology and risk analysis, nuclear medicine, biomedical engineering, analytical technologies, and computational biology and bioinformatics. The Laboratory's Complex Biological Systems Initiative, described in Sect. 4.2, is an integrated activity that draws on resources from these and other ORNL programs. This initiative includes the development of a new Center for Systems Biology, with a focus on understanding human susceptibility to low-dose radiation and to exposure to chemicals and mixtures of environmental insults.

ORNL proposes to integrate its resources to develop a biomedical engineering program in support of the missions of OBER and other federal agencies.

Biomedical Engineering and Bioengineering

Biomedical engineering and bioengineering (BME) research comprises the development of innovative technologies that could have a significant impact on health care. The Office of Biological and Environmental Research (OBER) within DOE's Office of Science manages an Advanced Medical Instrumentation (AMI) Program to bring the unique resources of DOE's national laboratories to bear on BME, with a major focus during the next few years on the development of innovative imaging technologies for medical use. This program is linked with BME research at other federal agencies through the Bioengineering Consortium (BECON), which spans all of the institutes of the National Institutes of Health (NIH), DOE, the National Science Foundation, the Defense Advanced Research Projects Agency, and other federal agencies.

ORNL has established a BME program to provide an integrating focus for a variety of efforts in such areas as medical telesensors, biosensors, medical diagnostics, nanoscience and nanotechnology development, biological systems modeling, and analytical technologies. Many of these are being pursued in or led from the ORNL Life Sciences Division. Other divisions, including the Chemical Sciences, Engineering Science and Technology, and Metals and Ceramics divisions, have ongoing efforts and strong interest in this area of research. A BME focus group includes researchers from across ORNL. The Laboratory's capabilities are leveraged by its membership in the Tennessee Biomedical Engineering Consortium.

Principal investigators at ORNL are carrying out three projects funded by the AMI Program in June 2001. Work also continues on the integration of microchannel glass and photosynthetic structures into photoelectrode array implants, with the aim of developing a retinal prosthesis; on the development of advanced fluorescence techniques for *in vivo* diagnosis; and on the application of high-throughput mass spectrometry for disease screening. A program to develop nuclear imaging of small mammals is being conducted in collaboration with the Thomas Jefferson National Accelerator Facility (JLab).

The ORNL BME program also draws on support from NIH, which will be a key element in attaining both the funding level and the scope envisioned for long-term success. The four focus areas of the NIH program—imaging, nanotechnology, tissue engineering (biomaterials), and informatics—cover a broad spectrum of research aligned with work in progress at ORNL.

To ensure success in this effort, ORNL will establish clear scientific goals, develop and expand strategic partnerships with academic centers of excellence and with medical centers (e.g., through the Joint Institute for Biological Sciences; see Sect. 4.2.6), and produce a program development plan that sets priorities and includes appropriate resources for proposal development.

5.1.2.2 • Environmental Sciences

Environmental science research covers biogeochemistry, environmental biotechnology, environmental chemistry, ecosystem studies, geosciences, hydrology, microbiology, and environmental assessment. Through the Energy and Environmental Systems of the Future Initiative (see Sect. 4.4), these capabilities will be applied to the development of a deeper understanding of large-scale environmental processes and global climate change and to strategies for carbon management and sequestration.

ORNL will continue its long and rich history of ecosystem research, maintaining its leadership role in the development of large-scale ecosystem manipulation experiments and ecosystem-based modeling. Major field-scale manipulations include the Free Air Carbon Dioxide Enrichment (FACE) experiment and the Throughfall Displacement Experiment (TDE). Starting its fourth growing season under elevated carbon dioxide, the FACE experiment integrates research on the response of both aboveground and belowground ecosystem processes to elevated carbon dioxide. The TDE has characterized the complex forest system response to precipitation changes. Fundamental processes (photosynthesis, tree and soil respiration, nutrient cycling, and carbohydrate storage) have been studied together to develop an integrated picture of the forest's response. A book synthesizing the research at this experimental site will be published in 2002. Research on the Walker Branch Watershed continues to elucidate the biogeochemistry of upland streams and the long-term vegetation dynamics of upland southern hardwood forests.

Modeling of global ecosystem response to climate changes is an important component of ORNL's ecosystem research. ORNL's LoTEC and GTEC terrestrial biogeochemistry models are used for analysis of global change impacts on terrestrial systems and feedbacks to the climate system. A modification of GTEC has been used in the Vegetation/Ecosystem Modeling and Analysis Project (VEMAP).

We are now working to couple the ORNL models to global circulation models (GCMs) to capture the feedbacks between terrestrial systems and the atmosphere. In collaboration with the ORNL Center for Computational Sciences, we are initiating a research program to create the next generation of coupled climate and carbon research models. This concept supports a new level of coordination in computer software engineering and earth systems model development. The plan is to link modeling and experimental research and apply high-performance computational capabilities to the problem. We are also actively participating, through the Biogeochemistry Working Group, in the development of carbon cycle representations of the terrestrial ecosystem for the Community Climate System model. Field research on soil carbon processes and global carbon emission analysis continues to enhance the global carbon modeling work.

Three new ecosystem projects began during FY 2001: a large-scale field experiment that will tease apart the decomposition pathways of aboveground and belowground litter by taking advantage of an accidental emission of ^{14}C that has differentially labeled plant tissues; a seedling open-topped chamber experiment that will examine the multiple effects of increased warming on tree growth processes; and a project that will use functional genomic approaches to elucidate the roles of genes in controlling cell wall properties in woody species and thus the long-term capture of carbon in forest ecosystems.

ORNL is also working with other DOE laboratories to establish a new Water Cycle Dynamics Program to develop better predictions of regional water resources as affected by changes in climate and land use. A pilot study centered on the ARM Southern Great Plains study area was funded by DOE in FY 2001. Program elements include computer simulation and visualization; regional testbeds in large river basins; innovative application of new environmental tracers, including stable isotopes; development of advanced observational networks; and management and archiving of very large environmental databases.

ORNL performs key roles in meeting DOE's needs for environmental data systems. Key tasks include developing integrated databases; collecting, analyzing, distributing, and archiving data; and performing a wide range of quality assurance functions.

The Carbon Dioxide Information Analysis Center (CDIAC), which includes the International Council of Scientific Unions–designated World Data Center for Atmospheric Trace Gases, is DOE's primary global change data and information analysis center. CDIAC responds to data and information requests from users worldwide who are concerned with the greenhouse effect and global climate change.

CDIAC's data holdings include records of the concentrations of carbon dioxide and other radiatively active gases in the atmosphere; the role of the terrestrial biosphere and the oceans in the biogeochemical cycles of greenhouse gases; fossil fuels and land-use emissions of carbon dioxide to the atmosphere; long-term climate trends; the effects of elevated carbon dioxide on vegetation; and the vulnerability of coastal areas to rising sea level.

CDIAC has become a model for the development of other data management systems in the international global change research program. The challenge for CDIAC is continued excellence in delivery of high-quality products. A recent example is ORNL's support, through CDIAC, of data management for the U.S. AmeriFlux network, which is a component of the larger FLUXNET Program, a multiagency effort aimed at integrating worldwide CO_2 flux measurements.

The Atmospheric Radiation Measurement (ARM) Program sponsors a data archive that supports the program's field experiments in near real time. These data are used to research atmospheric radiation balance and cloud feedback processes that are critical to understanding global climate change. To date, the archive has handled about 4.5 million files containing more than 12 terabytes of data.

ORNL supports the NARSTO partnerships whose mission is to plan, coordinate, and facilitate policy-relevant scientific research and assessment of primary and secondary atmospheric pollutant species emitted, formed, transformed, and transported in the troposphere over the North American continent. As NARSTO's Quality Systems Science Center, ORNL provides quality assurance and data management assistance, data archival and distribution, and data guidelines for NARSTO research planners, project managers, and principal investigators.

ORNL is continually seeking innovative and cost-effective ways to manage data for DOE and other agencies. Mercury, a Web-based system developed at ORNL, supports searches for metadata and retrieval of associated data. Mercury invokes a new paradigm for managing dynamic distributed scientific data and metadata, putting control in the hands of investigators. All of the data, documentation, and metadata reside on the individual data providers' servers. Mercury uses the Internet to form a "virtual system" interconnecting those servers and its central system. Through such innovative approaches, ORNL can make tremendous amounts of data available in a cost-effective manner for diverse research and modeling programs.

ORNL is also expanding research that focuses on harnessing microbial processes to remediate radionuclide and metals contamination in the subsurface in support of OBER's Natural and Accelerated Bioremediation Research Program (NABIR). OBER's first NABIR Field Research Center (FRC) is located on the Oak Ridge Reservation in the Bear Creek Valley near the Y-12 National Security Complex.

The FRC, which comprises a 100-hectare (243-acre) contaminated area and a 164-hectare (404-acre) uncontaminated area, will be used for long-term field studies to advance both the understanding of microbial interactions with groundwater and soil and the mechanisms for immobilizing metals and radionuclides or changing contaminants to less toxic forms. ORNL operates the FRC for OBER, carrying out hydraulic testing, tracer testing, groundwater and sediment sampling, and other characterization activities. The results of the initial tasks will be used in identifying areas for field studies to be conducted by scientists from DOE laboratories (including ORNL) and universities during the next 5 to 10 years. Researchers will use the FRC to develop an understanding of the complex factors affecting bioremediation and innovative means of enhancing the reactions of microbes with radionuclides, metals, and other contaminants. The FRC will also generate data that can be incorporated into the mathematically based numerical models that are an important tool in predicting and planning groundwater management programs and remediation strategies, and it will provide opportunities for comparing computational predictions of bioremediation techniques with actual outcomes. This work directly supports DOE's general goal for environmental quality (see Sect. 5.3).

ORNL's research on the microbial genome (see Sect. 4.2.3) emphasizes organisms important to global change, carbon sequestration, marine biotechnology, and bioremediation, building on Laboratory expertise in analyzing gene expression and on the NABIR FRC. Work on microbial community structure and function should provide a basis for understanding potential impacts of a changing climate on below-ground ecosystems. From this work, it may be possible to promote increased sequestration of carbon

below ground through alteration of microbial communities (e.g., by manipulation of native communities, by alteration of the community with organisms from other areas, or even by genetic manipulation). Our research should also lead to applied research and technology development on the processing of biomass for fuel and power.

ORNL proposes to expand its programs in large-scale environmental process and effects research as a means of developing new scientific approaches and facilities to understand the impacts of energy development and use on the environment.

Large-Scale Environmental Process and Effects Research

The fundamental plant and soil processes that determine how terrestrial ecosystems respond to physical and chemical changes in the environment are highly dynamic and active at temporal scales from nanoseconds to millennia and at spatial scales from single molecules to the global. ORNL has made notable contributions to the understanding of these processes, and its historic strengths in ecosystem studies, plant physiology, biogeochemistry, and modeling represent an unmatched resource for addressing present and future environmental questions.

There is, however, an urgent need to complement and extend these resources by establishing an enhanced program of research that leverages and integrates emerging ORNL capabilities in large-scale ecosystem manipulation, data management and retrieval, ecological modeling and visualization, measurement science and sensor development, computational science, and genomics.

In collaboration with other DOE laboratories, we are laying the foundation for what is expected to become a broad initiative that brings together strengths from across the DOE complex in the development of large-scale terrestrial ecosystems research facilities (TERFs). The projected collection of facilities will be of unprecedented scope in terms of both size and technology and will usher in a new era for monitoring, probing, and understanding the response of terrestrial ecosystems to rapid environmental change and human-caused perturbations. While still in the conceptual stage, the initial TERF is viewed as a test bed for quantifying the effects of energy by-products on ecosystem function. It will be a DOE centerpiece for assessing the impacts of global climate change on the essential services provided to society by ecosystems: atmospheric and climate regulation, flood control, provision of clean water, and recycling of waste products.

A unique focus of the TERF initiative will be the exposure of intact ecosystems to multiple factors, such as atmospheric carbon dioxide enrichment, rising temperature, and increased frequency of drought. Such multifactor studies are critically important because these climatic forcings will ultimately govern changes in the delivery of ecosystem goods and services, biogeochemical cycles, and biodiversity.

The DOE laboratories will integrate large-scale environmental process research with leading-edge capabilities for measurement, modeling, and monitoring of the environment to define and create new approaches to ecosystem process research. This will provide a nexus for the revitalization of ecological sciences through the development of advanced instrumentation, modeling, visualization tools, and distributed, community-based science. Strengths in information and data management will support the transfer of data from on-line sensors to other institutions worldwide via the Internet. Intensive data collection capabilities will also enable near-real-time modeling of plant, soil, and atmospheric processes and thus help to shape a new generation of high-performance computer models that can represent complex landscapes in unique dimensions of space and time. The creation of "virtual ecosystems" will benefit from and contribute to direct field experiments and open new avenues for conducting manipulative investigations in a high-performance computing environment.

This emphasis on experimental capabilities, instrumentation, and advanced simulation is critical to meet the research challenges of the coming decades and to fulfill DOE's mandate to protect the environment and human health.

ORNL also proposes to extend its work in carbon sequestration research through the multi-laboratory Center for Research on Enhancing Carbon Sequestration in Terrestrial Ecosystems (CSiTE).

Carbon Sequestration Research

The goal of DOE's carbon sequestration research program is to provide science-based understanding to support the development and assessment of strategies for enhanced carbon sequestration in terrestrial and ocean ecosystems. The objective of the research is to have this understanding by 2025 so that new strategies (if deemed acceptable) could be implemented during the middle of the 21st century.

The Center for Research on Enhancing Carbon Sequestration in Terrestrial Ecosystems (CSiTE) performs fundamental research to discover and characterize links between critical pathways and mechanisms for creating larger, longer-lasting carbon pools in terrestrial ecosystems. Research is designed to establish the scientific basis for enhancing carbon capture and long-term sequestration in terrestrial ecosystems by developing (1) scientific understanding of carbon capture and sequestration mechanisms in terrestrial ecosystems across multiple scales from the molecular to the landscape, (2) conceptual and simulation models for extrapolation of process understanding across spatial and temporal scales, (3) estimates of national carbon sequestration potential, and (4) assessments of environmental impacts and economic implications of carbon sequestration.

During the first 24 months of research, field studies have been established in forests, grasslands, agricultural systems, and degraded lands. Inquiries into microbial and molecular geochemical control on the quantity and quality of soil organic matter will suggest new strategies for enhancing sequestration. In addition, methods for estimating the net impact on greenhouse gas emissions via direct management for carbon sequestration have been developed. Models to assess both environmental and economic impacts resulting from energy-driven land management are being developed, improved, and tested. A terrestrial project initiated in FY 2001, "Genetic and Environmental Controls on Carbon Allocation and Partitioning in Woody Plants: Implications for Ecosystem Carbon Sequestration," will address aspects of carbon sequestration related to securely storing carbon in chemical forms that are resistant to microbial degradation and allocating carbon preferentially to roots, where it can better contribute to soil carbon sequestration. The research will take advantage of a genetically well-characterized population of hybrid poplars growing in the Pacific Northwest. For every individual in this population, the chemical composition of leaves and roots, and the fraction of total carbon allocated to roots, will be determined. These traits will be compared against a genetic map that is being established for hybrid poplar, and genes important to carbon sequestration will be identified.

ORNL is also investigating the potential environmental consequences (and methods to reduce any such consequences) of direct injection of carbon dioxide into the ocean with another new FY 2001 project. This study uses a combination of experiments and models to understand coupled hydrodynamic, geochemical, and biological processes in sinking carbon dioxide particle plumes in sea water, which are important in evaluation of deep ocean injection of carbon dioxide. This collaborative study with the Massachusetts Institute of Technology aims to develop predictive models for simulating spatial structure, physical and chemical dynamics, and responses of representative biota in the mixing zone of injected carbon dioxide particles and sea water. The ORNL Seafloor Process Simulator (temperature-controlled pressure chamber) will be used to measure physical and chemical changes in injected liquid carbon dioxide and surrounding sea water under conditions representative of the deep ocean.

To support the Oak Ridge Reservation Bioenergy and Carbon Sequestration Systems activity (see Sect. 5.2.1), we are beginning a process that will ultimately provide sites for testing terrestrial carbon sequestration technologies and evaluating their environmental and economic implications. These sites will be coordinated with bioenergy feedstock research activities to leverage research and land resources. Test sites for evaluating carbon sequestration approaches for agricultural, pasture, forest, and urban land uses will be developed. These sites will also be used for developing carbon measurement technologies and testing approaches for carbon accounting. This activity will provide a framework for moving the findings of the CSiTE to broader, more applied scales.

5.1.3 • Advanced Scientific Computing Research—KJ

The DOE-SC Office of Advanced Scientific Computing Research (ASCR) supports ORNL research in and application of mathematical, computational, computer, and communications sciences. This includes operating the high-performance computers at ORNL and conducting basic research through the Applied Mathematical Sciences (AMS) subprogram. The Terascale Computing and Simulation Science Initiative described in Sect. 4.3 will extend ORNL's computational resources and expertise to support DOE's missions.

The AMS subprogram supports research in three areas:

- The development of innovative approaches for high-performance scientific simulations on advanced architecture computers. Examples of novel approaches include empirical optimization of core linear algebra subprograms and parallel core numerical algorithms with reduced communications requirements.
- The development of tools to facilitate the use of parallel and distributed computing systems. These include software tools to support discretization and meshing for scientific simulation, shared-memory programming environments for distributed-memory architectures, and fast parallel input/output (I/O) for advanced computer architectures.
- The development of applied mathematical, statistical, and computational methods for use in areas requiring high-end computing, including solid and fluid dynamics, climate dynamics, astrophysics, fusion energy, chemistry, materials science, and biophysics. Examples include problem-specific preconditioners for Krylov-subspace iterative methods; advanced boundary integral methods that incorporate fast multipole and level set methods; high-order discretization methods for fast, accurate simulations; and immersed boundary methods for biophysical models.

ORNL is participating in the DOE2000 initiative to create and apply new computational tools and libraries for "national collaboratories" and advanced computational testing and simulation (ACTS). Activities include the Materials Microcharacterization Collaboratory (MMC); the ACTS Scientific Template Library; the Electronic Notebook project; and the Collaborative Management Environment project.

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

ORNL's Collaborative Technologies Research Center performs fundamental and applied research in intelligent software agents, information integration, and software engineering. It will play a role in ORNL's commitment to develop and integrate skills and facilities for computing, modeling, and simulation, as will the creation of a human simulation environment, the Virtual Human, described in Sect. 5.6.2.3.

ASCR also supports innovative, high-risk research that does not fall under the auspices of other DOE programs. The Laboratory Technology Research (LTR) Program supports research that integrates basic and applied disciplines to promote substantial changes in technologies of strategic importance to DOE's missions and to American industry. Activities include cooperative R&D agreements and collaborations with other national laboratories.

5.1.4 • Fusion Energy Sciences—AT

ORNL's Fusion Program is a strong and vital component of both the U.S. fusion program and the international fusion community. Fusion devices such as the DIII-D tokamak at General Atomics in San Diego and the National Spherical Torus Experiment (NSTX) at the Princeton Plasma Physics Laboratory (PPPL) support a broadly collaborative program to establish the science base for the development of fusion as an energy source. ORNL researchers carry out cross-cutting research in several topical areas on these facilities and on complementary facilities in other nations. Theoretical research on high-temperature plasmas uses state-of-the-art computing methods (see Sect. 4.3.3.3) 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 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; develops laser-based alpha particle diagnostics; and conducts a variety of R&D projects applying fusion-related technologies and expertise to other fields. Nonfusion applications address such areas as plasma processing and propulsion, high-temperature superconducting power transmission systems, and power grid reliability (building on self-organized criticality theory).

ORNL's expertise is well matched to the increased emphasis being placed on innovative confinement concepts by the U.S. fusion program. The U.S. spherical torus program, which originated at ORNL, is now centered on the NSTX. ORNL is a major participant in the NSTX physics program.

ORNL is also deeply involved in the growing national stellarator program. The Laboratory is partnering with PPPL to develop the National Compact Stellarator Experiment, to be constructed at PPPL, and is working with PPPL, the University of Tennessee, and other universities to build a complementary facility, the Quasi-Poloidal Stellarator (QPS), at ORNL.

Quasi-Poloidal Stellarator

The Quasi-Poloidal Stellarator (QPS) is proposed as a means of obtaining new physics results on confinement of plasmas in an innovative geometry and exploring the potential of this compact variant of the stellarator approach as a more attractive fusion power reactor. In the long term, the QPS approach could lead to a reactor that combines the best features of stellarators (low recirculating power, leading to higher efficiency and the absence of potential plasma disruptive events) and the mainline tokamaks (compactness and good plasma performance).

The concept exploration (CE)–level QPS (see Fig. 5.2) can make unique contributions to the development of the compact stellarator, which has been identified as the U.S. focus for improvement of the stellarator concept. These contributions include

- exploration of the key issues for a compact stellarator reactor with high beta ($\langle\beta\rangle = 10\%$) and low aspect ratio ($R/a = 2.7$) and
- exploration of the physics consequences of very low aspect ratio and quasi-poloidal symmetry for the optimization of compact stellarators.

This information is needed within the next 10 years to meet the objectives laid out by the Fusion Energy Sciences Advisory Committee (FESAC) for the compact stellarator and to serve as input for decisions on the next step in the world stellarator program, following the Large Helical Device and Wendelstein VII-X (W7-X). A large world stellarator program is focusing on the high-aspect-ratio, currentless approach to stellarator optimization, and a CE-level stellarator program is exploring unique aspects of stellarator research. Missing, however, is work to optimize stellarators at low plasma aspect ratio that could lead to a more attractive fusion reactor than either the advanced tokamak or the conventional currentless stellarator.

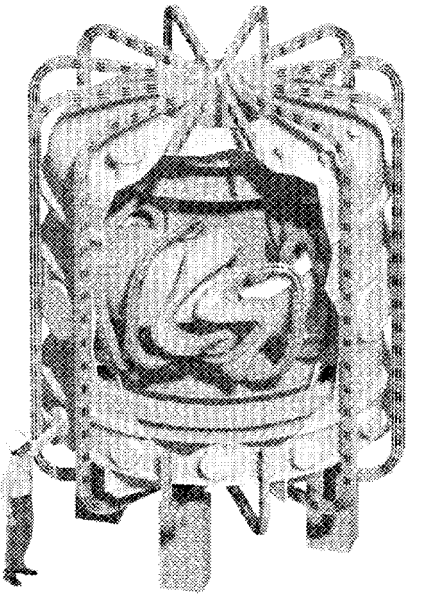

Figure 5.2
Schematic of the QPS.

The QPS will provide an experimental database from which it should be possible to predict the behavior of a low-aspect-ratio, high-beta stellarator. A CE-level experiment, although limited by heating capability to relatively low beta ($\beta < 3\%$) compared to the reactor embodiment, would allow the exploration of key physics issues relevant to transport (both neoclassical and anomalous) and stability in a configuration with quasi-poloidal symmetry. The study of the physics of quasi-poloidal symmetry at very low aspect ratio in a stellarator with finite bootstrap current, at finite beta, uniquely differentiates the QPS from W7-X.

The QPS could make unique contributions to some of the key fusion science area outlined by DOE's Integrated Program Planning Activity: the physics of neoclassical confinement improvement at very low aspect ratio, the robustness of flux surfaces at $\langle\beta\rangle$ up to 2–3% in the presence of strong toroidal/helical coupling, the dependence of bootstrap current on configuration properties at low aspect ratio, and the electric potential and its influence on enhanced confinement regimes.

In spring 2001, successful DOE physics validation and project validation reviews established the mission need for the QPS. A conceptual design, cost, and schedule review is planned for April 2002. First plasma under the proposed schedule is projected to be produced near the end of FY 2006.

The ORNL Fusion Program is also applying its strengths in collaboration and strategic alliances to the Virtual Laboratory for Technology (VLT), established by the DOE-SC Office of Fusion Energy Sciences to unify and coordinate the U.S. effort to meet emerging needs in fusion technology. The VLT links the geographically distributed experimental, computational, and information resources of the fusion community, drawing on high-performance research tools that allow scientists and engineers across the country to work together in new ways.

Under the aegis of the VLT, ORNL is the lead laboratory in the areas of fueling and rf technology. Programs in both areas consist of basic development of new techniques, application of these new techniques to existing fusion experiments, and collaborations with both U.S. and international laboratories on experiments in these areas. In the fueling area, ORNL researchers have developed improved pellet injectors and have installed them on many major experimental devices [e.g., the Tokamak Fusion Test Reactor, DIII-D, the Joint European Torus (JET)], and have carried out experiments that have led to improved understanding of particle transport, as well as achieving improved operating states of the machines. In the rf technology area, ORNL leads a research program to understand the factors limiting the operation of rf antennas on present-day devices, and to develop improved rf systems for use on future machines. Collaborations are carried out with DIII-D, NSTX, Alcator C-Mod, ASDEX-U, and other experiments. ORNL is building a high-power prototype of an advanced rf antenna for the JET experiment in a major international collaboration.

Through a new SciDAC project on numerical computation of wave-plasma interactions in multi-dimensional systems, ORNL will be collaborating with other members of the rf theory community and the computer science community to extend the physics generality of the theories and to attack major unsolved problems in wave-plasma interactions, with immediate implications for ongoing experiments.

As part of ORNL's Facilities Modernization Initiative (see Sect. 7.3), plans are being made to move the ORNL Fusion Energy Division from the Y-12 National Nuclear Security Complex to the main ORNL campus. ORNL and DOE are working together to secure a new multipurpose research facility in the Melton Valley area. Implementation of these plans will begin in FY 2002, and the move should be complete by the end of FY 2006.

5.1.5 • Nuclear Physics—KB

The ORNL Nuclear Physics Program emphasizes basic nuclear physics research, both experimental and theoretical, and operates the Holifield Radioactive Ion Beam Facility (HRIBF) and the Oak Ridge Electron Linear Accelerator (ORELA) for nuclear structure physics and nuclear astrophysics.

At higher energies, ORNL has a leadership role on PHENIX, one of the two major experiments at the Relativistic Heavy Ion Collider at the Brookhaven National Laboratory, and is exploring involvement in the ALICE experiment under development at the European Laboratory for Particle Physics (CERN) in Geneva.

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.

A theoretical nuclear physics program provides support to both the nuclear astrophysics and nuclear structure programs. Research in nuclear structure theory takes advantage of the opportunities presented by the joint ORNL–University of Tennessee (UT) nuclear structure theory program. ORNL and UT are also working together, in collaboration with the National Center for Supercomputer Applications and seven other universities, on a Scientific Discovery through Advanced Computing (SciDAC) project to develop a standard mode for core collapse supernovae.

The ORELA is a unique, intense pulsed-neutron-source accelerator facility for reaction measurements by time-of-flight neutron spectrometry. The ORELA program is directed toward basic research in nuclear astrophysics and fundamental interactions. Measurements made on ORELA also support DOE's Nuclear Criticality Safety Program (see Sect. 5.4).

Studies of the feasibility of using ORELA to test the performance of actinide targets designed for use in high-power beams (e.g., at an advanced RIB facility) and to produce radioactive species from the electron-induced fission of actinide targets yielded encouraging results and provide a basis for exploring the development of a high-power target test facility and a production facility for neutron-rich RIBs.

To broaden the understanding of nuclear structure, nuclear astrophysics, and nuclei subjected to extreme temperatures, rotational frequencies, and pressures, ORNL proposes to continue and expand its support of DOE and national needs for nuclear physics with RIBs.

Nuclear Physics with Radioactive Ion Beams

Radioactive ion beams (RIBs) afford a range of scientific opportunities, including the ability to study such topics as

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

The Holifield Radioactive Ion Beam Facility (HRIBF) at ORNL, an isotope separator on-line (ISOL) facility for the production of accelerated beams of radioactive isotopes, is the first U.S. RIB facility devoted to low-energy nuclear structure and nuclear astrophysics research. Radioactive ions are produced when intense beams accelerated by the Oak Ridge Isochronous Cyclotron (ORIC) are directed onto thick, refractory targets. The radioactive elements diffuse out of the target, are ionized, and are mass selected for injection into the 25-MV tandem accelerator, producing beams of 0.1–10 MeV per nucleon for light nuclei and up to 5 MeV per nucleon for mass 80. These beams are ideal for research in nuclear astrophysics and nuclear structure.

An advanced ISOL facility for the production of accelerated beams of radioactive isotopes was identified in the 1996 Long-Range Plan for U.S. Nuclear Science, prepared by the DOE/National Science Foundation (NSF) Nuclear Science Advisory Committee (NSAC), as the next major facility to be constructed for U.S. nuclear science. This facility would provide the larger variety of more intense RIBs needed to take full advantage of the opportunities in this new interdisciplinary research field.

The DOE Nuclear Physics Program is now considering the design and construction of a rare-isotope accelerator (RIA) facility based on a highly flexible superconducting linear accelerator (linac) driver, with the capability for fast in-flight separated beams of rare isotopes. The projected cost of the RIA facility, assuming the start of construction in FY 2002, is about $800 million, with operation beginning after 2010.

At the request of the DOE Nuclear Physics Program, ORNL has examined ways of upgrading the HRIBF that would enhance the competitive position of RIB research in the United States until the new facility can be completed. A number of upgrades, with costs ranging from $1 million to $30 million, have been identified. ORNL will continue to work with the Nuclear Physics Program to determine appropriate options for expanding the use of RIBs.

In addition, ORNL is developing, in collaboration with scientists at other national laboratories and several universities, a proposal for the construction and operation of a facility at the Spallation Neutron Source (SNS) for fundamental neutron physics studies. The current design is for two beam lines, one for cold and the other for ultra-cold neutron experiments. This approximately $8 million project will provide a user facility for measurements of such fundamental neutron properties as lifetime, beta decay, and electric dipole moment. The project has received strong endorsement in the *Long-Range Plan for Nuclear Science*, which was recently completed by the Nuclear Science Advisory Committee for the DOE and the National Science Foundation (NSF). A workshop held in September 2001 covering science prospects at this facility attracted over 75 scientists from around the world.

ORNL also continues to believe that construction of the Oak Ridge Laboratory for Neutrino Detectors (ORLaND) at the SNS would offer the scientific community a unique facility for the study of neutrino science. However, current community interest in other possible neutrino projects has put ORLaND on hold. It is anticipated that many of the collaborators on the project will continue to refine its design and program in order to make a stronger case for the project in future years.

5.1.6 • High Energy Physics—KA

ORNL's High Energy Physics Program is focused in three areas: (1) the development of high-power targets for use in projects such as the neutrino factory and the muon collider; (2) the development of particle detectors, including their design and construction; and (3) the development of radiation transport codes and other codes that can be used in the design of particle detectors, shielding, and high-power targets. Current activities include research on the neutrino factory and muon collider with Fermi National Accelerator Laboratory, Princeton University, and Brookhaven National Laboratory; target testing at Los Alamos National Laboratory and Brookhaven National Laboratory; and development of the CALOR00 code system, a key tool for radiation transport analysis.

5.1.7 • Energy Research Analyses—KD

ORNL assists the Energy Research Analyses program in technical reviews of DOE research programs. This includes technical support for peer review assessments and other studies and workshops as requested.

5.2 • Energy Resources

5.2.1 • 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's Office of Energy Efficiency and Renewable Energy (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.

This integrated approach is a key element for the Energy and Environmental Systems of the Future Initiative (see Sect. 4.4).

Five DOE-designated national user facilities with unique collections of research equipment for energy R&D are available: the Bioprocessing Research Facility, the Buildings Technology Center, the High Temperature Materials Laboratory, the Metals Processing Laboratory User Center, and the National Transportation Research Center. These facilities and other resources at the Laboratory enable the EE/RE program to address the energy R&D needs of the buildings, industry, power, and transportation sectors. ORNL proposes to expand its support for these needs by constructing a new Energy Efficiency Research Laboratory.

Energy Efficiency Research Laboratory

A laboratory/office building that will house R&D capabilities critical to the success of the Energy Efficiency and Renewable Energy (EE/RE) Program is being proposed for project engineering and design in FY 2003 and for construction in FY 2004–2005. The facility will provide expanded laboratory space, controlled testing, and analytical capabilities necessary to meet DOE programmatic and industry partnership needs. In addition, the new facility will enable ORNL to move into emerging research areas and will provide new capacity for current laboratories now located in outdated facilities that do not provide needed functionality and are expensive to occupy and maintain.

The Energy Efficiency Research Laboratory will support the missions and goals of three strategically important areas of R&D: distributed energy resources, high-temperature superconductivity (HTS), and buildings research. Their strategic importance is highlighted in the 2001 *National Energy Policy* report.

The facility will expand the building science R&D facilities at ORNL's Buildings Technology Center to take full advantage of partnering and cost-sharing opportunities in the areas of advanced appliance R&D and thermal performance of integrated building subsystems. The facility will serve as the hub of HTS research at the Laboratory and will be critical to ORNL success in DOE's Accelerated Coated Conductor Initiative. HTS experimental laboratories are now scattered throughout 5 buildings at ORNL and the Y-12 National Security Complex. Many of these laboratories are in substandard space that is not easily accessible to outside collaborators. The new facility will also serve as a technology development and demonstration site for building heating and cooling and for distributed energy technologies. With the new capabilities, we will be able to test, analyze, modify and retest new technologies, components, and systems; formulate and validate models; and predict the effects of product improvements with a high degree of certainty.

The facility will be the cornerstone of the new north entrance to the ORNL campus to be developed as part of our Facilities Modernization Initiative (see Sect. 7.3.3) and will be readily accessible to industrial and university partners. The 52,000-ft^2 building will provide space for research staff (including visiting researchers); a conference room, including video conference capability; and state-of-the-art laboratories for material, component, and system development and testing. We are committed to achieving the highest Leadership in Energy and Environmental Design (LEED) certification attainable within the constraints of project funding. We will also seek Federal Energy Management Program design assistance and a DOE/EPA Energy Star rating for the office portion of the facility.

During the past several decades, electricity's share of U.S. primary energy use has been steadily increasing; in 1999, energy used to generate electricity accounted for 40% of the nation's total energy consumption. To support DOE's work on **power technologies**, 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 distributed energy resources; superconductivity; power transmission and distribution; biopower; hydrogen production, use, and storage; hydropower; and international energy collaborative programs.

Activities in high-temperature superconductivity (HTS) are focused on development of superconducting wires that are able to carry 100 times the current of comparable copper wire, with the key advantage of zero electrical resistance (see Fig. 5.3). Research on second-generation "coated conductors" will lead to cost-effective HTS tapes. In collaboration with Los Alamos National Laboratory and key industrial and university partners, ORNL will improve its facilities and equipment in order to accelerate the development of these wires using technology adapted from the semiconductor and film processing industries.

Figure 5.3
Visitors to ORNL examine equipment used for sputtering buffer layers for high-temperature superconducting wire. Studying the equipment are, from left, Charles Cook of the House Science Committee staff and Debbie Haught and Roger Meyer of DOE-EE's Office of Power Technologies.

In addition, precommercial prototype power systems such as underground transmission and distribution cables, transformers, generators, and industrial-class motors are developed and tested in collaboration with U.S. industry and electricity suppliers. This equipment will help to improve the reliability of the nation's electricity system and increase the efficiency and productivity of energy use. ORNL's extensive resources in materials science and physical properties of superconductors; cryogenics research and development; and superconducting equipment research will support the development of the next generation of electric power equipment.

Distributed Energy Resources

Electricity demand in the United States is projected to increase by more than 1 trillion kWh over the next 20 years, requiring an additional 300 GW of generating capacity. Although large, central power stations have historically been more efficient than smaller systems, technological advances are producing small, modular equipment that is cleaner and more efficient than large systems. These small-scale power systems located close to the point of use are referred to as distributed energy resources (DER).

These systems incorporate the entire range of renewable energy sources, advanced technologies such as fuel cells and microturbines, and more conventional elements such as energy storage and reciprocating engines. In addition to power, DER systems can produce space heating, cooling, and dehumidification. The generated power and space conditioning are used by industrial or commercial concerns, and excess power can be fed into the central power supply grid.

The development of DER is a strategy that accomplishes several objectives. For businesses, DER can reduce peak demand charges, decrease overall energy use, provide a hedge against grid reliability problems, ensure power quality, and reduce emissions. For large utilities—power producers—DER can augment overall system reliability, avoid large investments in transmission system upgrades, reduce transmission losses, closely match capacity increases to demand growth, and open markets in remote or environmentally constrained areas.

ORNL has strong R&D capabilities in combustion technology, emissions characterization and mitigation, and materials development for advanced reciprocating engines and turbine systems (see Fig. 5.4). We are extending this

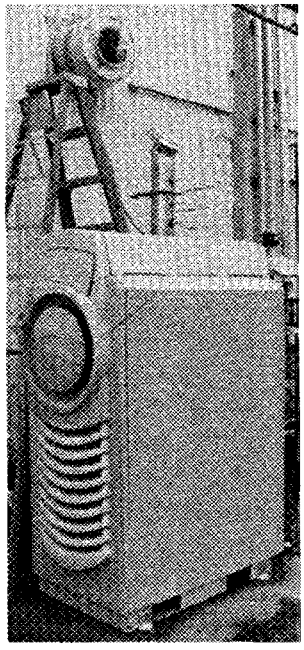

Figure 5.4
A microturbine at the Buildings Technology Center. Waste heat generated by the microturbine is routed to a desiccant dehumidification unit and an absorption chiller via the ductwork above the microturbine.

expertise to smaller gas turbines. Both solid oxide and proton exchange membrane fuel cell systems and components are being developed (see Sect. 5.2.2). Many aspects of electric power systems are being investigated, including transmission and distribution, interconnection of DER resources, reliability, restructuring, advanced control systems, and simulation and modeling.

ORNL also has expertise in the base technology areas of power electronics, high-temperature superconductivity, sensors and controls, materials and manufacturing processes that support DER technologies. In October 2000, ORNL and EPRI PEAC Corporation hosted a workshop on power electronics for distributed energy resources, sponsored by the DOE Office of Energy Efficiency and Renewable Energy and the DOE Office of Fossil Energy.

ORNL's extensive resources in materials science; combustion and emissions technologies; and heating, cooling, and ventilating equipment will support the development of distributed energy resource technologies and systems.

We are working to develop an expanded program in emissions characterization and control for DER generators. We are also developing a national communications network for the DOE program.

The nine most energy-intensive industries—agriculture, aluminum, chemicals, forest products, glass, metalcasting, mining, petroleum refining, and steel—participate in DOE's Industries of the Future (IOF) initiative, which assists these industries in cutting their nonproductive energy use and environmental costs. In support of DOE's **industrial technologies** efforts, ORNL is working with all of these industries on projects that address science and technology barriers identified by industry in visioning and roadmapping processes. For example, the steel IOF program is supporting the development and demonstration of *in situ* quality monitoring systems. One such project, the Galvanneal Temperature Measurement System, won an R&D 100 Award in 1999. 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. Technology support to the DOE Motor, Steam, and Compressed Air Best Practices Program includes the development of measurement and validation tools and techniques. New equipment and processes are investigated, ranging from improvements in heat transfer equipment to "bioreactors" that convert sugars (instead of today's petroleum feedstocks) to industrial chemicals.

The DOE-EE Office of Industrial Technologies also sponsors several ORNL programs in measurement science research. The Sensors and Controls Program is supporting the development and demonstration of distributed wireless sensor systems, which allow for upgrades and retrofits of energy efficiency–enhancing technology into existing plants without the expense of rewiring these plants. A flexible architecture to determine the optimal amount of intelligence and communication bandwidth between sensors and the distributed enterprise control system is under development. The use of value derivative analysis to determine sensor system insertion in complex processes for optimal energy

efficiency is also being demonstrated. These projects are focused on energy savings and productivity-enhancing applications in energy-intensive industries. The integration of ORNL capabilities in separations, bioengineering and biosciences, and chemical processing in the Center for Separations and Chemical Processing, described in Sect. 5.2.2, will support industry needs in energy efficiency and pollution prevention.

ORNL research in **buildings technologies** spans several areas. The Buildings Technology Center is a key resource for these efforts. Advanced refrigeration and appliance technologies are examined to improve energy efficiency and environmental quality. The search for viable ozone-safe alternatives to chlorofluorocarbons (CFCs) has been an important part of both equipment and materials research. Materials research focuses on technologies for high-efficiency, long-lived building insulation. ORNL's building envelope research examines how buildings function as an integrated whole—how roofs, windows, walls, and other building elements interact to affect energy efficiency. Researchers also conduct R&D on innovative walls, roofs, and foundations and on enhancing indoor environments through moisture control. 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, technical assistance with the incorporation of innovative materials and technologies in buildings, and hybrid lighting concepts. ORNL also provides technical assistance and evaluation support to DOE's Weatherization Assistance Program.

ORNL provides technical support to the Federal Energy Management Program in the demonstration of new technologies, energy audits in federal buildings, and innovative financing through the Super Energy Saving Performance Contract (ESPC) to facilitate energy-related improvements in federal buildings in the southeastern United States. ORNL also provides technical support for the technology-specific Geothermal ESPC and for combined heat and power projects at federal facilities.

In 1999, the **transportation** area accounted for about 28% of the nation's energy use and about two-thirds of its oil consumption. Imports of petroleum (almost $67 billion in 1999) and of automotive vehicles, engines, and parts ($180 billion in 1999) account for 24% of U.S. goods imports, while motor vehicle and equipment manufacturing is the largest U.S. manufacturing industry. Transportation is also the source of about one-third of the total U.S. carbon dioxide 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 broad transportation R&D program, the largest and most diversified in the DOE system, supports not only the needs of DOE, but also those of other federal agencies and industry. The program addresses materials, ignition and combustion, alternative fuels (including biofuels), transportation data and policy analysis, and innovative manufacturing and finishing processes. Most of ORNL's transportation research for DOE-EE is performed in support of the Partnership for a New Generation of Vehicles, the 21st Century Truck Program, and the Bioenergy Initiative. Near-term activities include the implementation of the 21st Century Truck Program and the refocusing of the Partnership for a New Generation of Vehicles. These programs are focused on developing efficient, clean, economically viable technologies for the transportation industry, supporting the goals of ORNL's Energy and Environmental Systems of the Future (E^2SF) Initiative (see Sect. 4.4). ORNL also carries out investigations of 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, for the U.S. Department of Defense (DOD), the U.S. Department of Transportation (DOT), the U.S. Department of Commerce, the Environmental Protection Agency (EPA), the Bureau of Transportation Statistics, and other sponsors.

During the planning period, transportation R&D will capitalize on the synergies of multiple sponsors and industrial partners, building on the resources available through the National Transportation Research Center (NTRC), as discussed in Sect. 5.6.3.4. The NTRC, a partnership of DOE, ORNL, and the University of Tennessee (UT), provides a mechanism for promoting and supporting research activities focused on major transportation R&D issues related to energy, environment, and security for

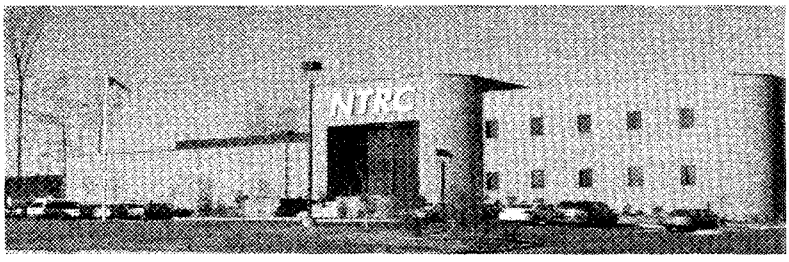

Figure 5.5
The National Transportation Research Center, December 2000.

the nation and the world (see Fig. 5.5). It is located in a new facility in Knox County, between ORNL and UT's Knoxville campus, that was constructed through a collaborative effort involving DOE, ORNL, UT, and the Development Corporation of Knox County. The NTRC was formally designated a national user facility in FY 2001.

ORNL's expertise in materials, engines and emissions, power electronics and electric machines, and alternative fuels will be key to its delivery of transportation R&D for DOE and other sponsors. An important element of this effort will be the development of expanded resources for carbon composites research.

Carbon Composites Research for Transportation

In FY 2001, ORNL and the Automotive Composites Consortium completed a design study to maximize the weight reduction of a vehicle through the use of carbon fiber–reinforced polymer composites rather than steel. This design study demonstrated the potential to reduce the weight of body and chassis components by 67%, significantly increasing a vehicle's fuel economy and reducing its emissions. Thermally conductive carbon foams are also of interest for other automotive applications, such as radiators.

ORNL has extensive expertise in the development and application of these materials and is DOE's coordinating laboratory for research in carbon fiber–reinforced polymer composites for automotive applications. Currently funded research is addressing low-cost fiber precursor; precursor processing into carbon fiber; polymer composite processing, bonding, finishing, and repair; and durability of polymer composites in automotive environments.

Partnerships have been established with all of the major players in the carbon composite, carbon fiber, and polymer composite industry. Work is under way to leverage these individual partnerships and create a consortium with a single vision to promote unified growth of the industry. ORNL has also worked with the automotive and truck industry to prepare plans for the development of carbon fiber–reinforced polymer composites and thermally conductive carbon foams. High-thermal-conductivity graphite foam, which has a thermal conductivity equivalent to that of aluminum at one-fifth of its weight, has numerous potential commercial applications. Developed by ORNL and Poco Graphite, the material received an R&D 100 award in 2000.

Most of ORNL's carbon fiber polymer composites research is now housed in facilities at the Y-12 National Security Complex. ORNL is working to establish a new research facility focused on all phases of carbon fiber research. This facility would also house new equipment required to support work in fiber preforming and polymer composite molding and expanded R&D on thermally conductive carbon foam. The expectation is that this facility will be constructed with third-party financing. ORNL staff will continue working with DOE program managers to ensure that appropriate budget requests are submitted to provide growth in the research program and procure capital equipment. ORNL will also continue to develop and maintain strategic relationships at all appropriate levels of DOE, other federal agencies, the prime automotive, truck, and transportation companies, and their suppliers and collaborators.

Biomass energy systems use the solar energy captured by green plants in biomass to produce electricity, heat, liquid transportation fuels, and biobased chemicals. The ORNL Bioenergy Feedstock Development programs conduct R&D to increase the supply of low-cost, sustainable biomass for the power and transportation sectors. Several ORNL divisions work with a large network of universities, U.S. Department of Agriculture research facilities, industries, and other national laboratories. Their goal is to integrate the plant science, environmental, engineering, and economic elements of biomass production in the development of efficient and environmentally acceptable biomass supply systems. The research emphasizes integrated resource, economic, and environmental analysis; the development of new energy crops; engineering studies and analysis, and environmental research. The Laboratory also conducts R&D in the rapidly advancing bioprocessing area. The bioprocessing efforts emphasize (1) systems that will economically produce fuels and chemicals from renewable feedstocks and waste materials and (2) technologies to deal with environmental concerns resulting from energy-related activities.

The National Renewable Energy Laboratory (NREL) is a major partner in ORNL's bioenergy research, and ORNL and NREL are co-leaders of the National Bioenergy Center established in November 2000. This close working relationship assists both laboratories in meeting the needs of DOE's bioenergy programs, which currently fund feedstock development work primarily through ORNL and conversion research primarily through NREL. Collaboration between the two laboratories emphasizes life cycle and economic analyses of entire bioenergy systems. Other joint efforts include technical collaboration on issues at the interface of biomass production and biomass processing, such as standards for biomass feedstocks, and a joint Laboratory Directed R&D (LDRD) project to map the genes that control carbon allocation and partitioning above and below ground in woody crop species.

ORNL proposes to use the Oak Ridge Reservation, including the ORNL campus, to create an integrated test bed for R&D on carbon sequestration technologies and bioenergy and bioproduct systems and their impacts. This activity will be closely linked to strategic directions in large-scale environmental process and effects research and in carbon sequestration research (see Sect. 5.1.2.2).

Oak Ridge Reservation Bioenergy and Carbon Sequestration Systems

Bioenergy systems and carbon sequestration systems share two fundamental attributes: both use land, and both reduce net carbon emissions to the atmosphere. Accordingly, there is much to be gained in researching, analyzing, and demonstrating these systems in an integrated way, and certainly the adoption of either of these systems will influence the other. Both systems are affected by soils, climate, and existing patterns of land use and therefore by the associated environmental concerns—maintenance or enhancement of soil productivity, biodiversity, hydrology, and water quality. An understanding of the short-term and long-term carbon benefits of both systems will be crucial to their promotion and adoption.

The purpose of the Oak Ridge Reservation Bioenergy and Carbon Sequestration Systems activity is to make use of the Oak Ridge Reservation, including the ORNL campus, to create an integrated test bed for R&D on terrestrial carbon sequestration technologies and bioenergy and bioproduct systems and their impacts. This activity has five key elements:

- fueling the west end of the ORNL campus with bioenergy derived from locally produced feedstock;
- using both forested watersheds and agricultural land on the reservation for research, demonstration, and environmental analysis of carbon sequestration and bioenergy feedstock production;
- creating commercially viable energy crop production on nearby private agricultural land;
- performing a thorough carbon accounting of all activities on the Oak Ridge Reservation; and
- developing outreach activities (e.g., tours, displays, and brochures) to showcase an integrated vision of bioenergy and carbon sequestration and the energy-driven land management associated with these aims.

This activity will provide needed opportunities for full-system research and analysis of both bioenergy and carbon sequestration technologies, including their economic and environmental impacts. It will provide opportunities for identify-

ing and quantifying possible synergisms or complementarities of the two sets of technologies. Integrally linked to both the National Bioenergy Center and the Center for Research on Enhancing Carbon Sequestration in Terrestrial Ecosystems (CSiTE), it will showcase DOE research and technologies in an accessible fashion, help to jumpstart bioenergy industries in Tennessee, and provide a technology development blueprint for other regions. Finally, it will provide a structure for capturing and synthesizing bioenergy and carbon sequestration research across ORNL and, of necessity, will foster ties with universities and state and federal agencies that conduct land management research.

We are beginning a process that will ultimately lead to the use of bioenergy from local feedstock to fuel the ORNL West Campus. We will work with the bioenergy industry to identify the commercial bioenergy conversion technology most appropriate for integration into the energy mix needed for this area. Feedstock for the conversion facility is expected to come from a variety of sources—primarily energy crops produced by local farmers, but also harvest from energy crop research plots and forest residues from forest management research plots on the Oak Ridge Reservation.

Key to this activity will be economic and environmental research to clarify and quantify the impact of the bioenergy technology, including the associated land management activities. A careful accounting of the energy and carbon flows of the complete bioenergy system will be kept.

Partnerships with industry, other national laboratories, universities, state agencies, and U.S. Department of Agriculture and Environmental Protection Agency laboratories with be essential to making this vision a reality. Building and sustaining these partnerships will be a key task for this activity.

5.2.2 • Fossil Energy

ORNL is engaged in R&D programs for DOE's Office of Fossil Energy (DOE-FE) that address coal, oil (petroleum), and natural gas. ORNL also provides support for the Innovative Clean Coal Technology (CCT) Program and for the Strategic Petroleum Reserve.

The ORNL Fossil Energy Program embodies a broad range of research, including advanced structural and functional materials, bioprocessing, combustion, carbon sequestration, gas production and utilization, and oil production and environmental technologies.

The Fossil Energy Advanced Research Materials Program includes the development of (1) coatings and protection of materials; (2) high-temperature corrosion-resistant alloys with unique properties; (3) functional materials such as hot-gas filters (alloys and ceramic composites), ion transport membranes, and activated carbon materials; and (4) ultrahigh-temperature (>1000°C) materials including alloys and ceramic composites. ORNL has a major technical management role, with DOE's National Energy Technology Laboratory (NETL), in the Advanced Research Materials Program.

ORNL is a major participant in the Advanced Turbine Systems (ATS) Program, which has been jointly planned and executed by DOE-FE and DOE-EE. ORNL has worked with Howmet and PCC Airfoils in the development of processes to fabricate single-crystal turbine blades for large land-based gas turbines. ORNL R&D has focused on materials and fabrication methods for thermal barrier coatings and environmental barrier coatings and on materials evaluation. In an effort involving Solar Turbines Inc. (an ATS Program developer) and ORNL's Advanced Research Materials Program, a major advance was achieved in strengthening the alloy used in a high-temperature recuperator for Solar Turbines' Mercury 50 gas turbine and increasing its use temperature. Solar Turbines also leads one of three projects, begun in July 2000, through which ORNL is working with industry partners to develop advanced material technologies that support the use of gas turbines in distributed generation.

ORNL has provided significant support to the CCT Program. ORNL led the environmental impact analysis activity for the total program, which resulted in publication of the Programmatic Environmental Impact Statement, and conducted environmental impact analyses for several individual CCT projects, notably the Healy, Alaska, project involving a coal-fired power station on the border of the

Denali National Park. Materials failure analyses have also been conducted for the CCT Program. Significant and unanticipated materials issues have been addressed and solved.

The ORNL Fossil Energy Program is engaged in three major initiatives: fuel cells and functional materials, carbon sequestration, and methane hydrates. These areas were identified as offering potentially significant opportunities for new R&D that would take advantage of ORNL talents and competencies. All three support the Energy and Environmental Systems of the Future Initiative described in Sect. 4.4.

The fuel cells and functional materials initiative is focused on materials processing and fabrication of (primarily) solid oxide fuel cell components and ion transport membranes for oxygen and hydrogen generation. ORNL's aim is to become a major participant in the DOE-FE fuel cell program through the Solid State Energy Conversion Alliance (SECA) organized by NETL and the Pacific Northwest National Laboratory. ORNL has been identified as a core team member in SECA and expects to have major roles in materials processing and fabrication and in power electronics, particularly inverter technology. An October 2000 workshop on power electronics for distributed energy systems, hosted by ORNL, included SECA activities that support the application of distributed energy resources (see Sect. 5.2.1). The initiative has led to a noteworthy collaboration between ORNL and ZeTek Power Company, a leader in alkaline fuel cell technology. ORNL and ZeTek are developing a fuel and oxidant processor based on ORNL's carbon fiber composite molecular sieve and electrical swing adsorption technologies.

Carbon sequestration R&D is a rapidly growing component of the DOE-FE R&D program. Appropriations for FY 2001 were about $10 million. Three ORNL projects specifically related to carbon sequestration are funded by DOE-FE. The Environmental Sciences Division and the Metals and Ceramics Division are collaborating on a project involving biomineralization for carbon sequestration. ORNL is also a team member of GEO-SEQ, a public-private partnership led by the Lawrence Berkeley and Lawrence Livermore national laboratories. This project is performing R&D to deliver information and technologies for the safe and cost-effective geologic sequestration of carbon dioxide. The third project involves R&D to support optimal selection and delivery strategies to maximize carbon sequestration and reclamation of degraded land using fossil fuel combustion byproducts. This project is a complement to the Center for Research on Carbon Sequestration in Terrestrial Ecosystems (CSiTE) described in Sect. 5.1.2.

DOE-FE's R&D program in methane hydrates is intended to lead to the safe and environmentally acceptable production of methane from this unconventional source. The program has four topic areas: resource characterization and evaluation; seafloor stability and safety; climate change implications; and production. ORNL organized and is leading a national laboratory council to coordinate research efforts and to promote interlaboratory collaboration on methane hydrates R&D. ORNL is also using Laboratory Directed R&D (LDRD) funds to conduct several projects, including the Seafloor Process Simulator (a 70-L pressure vessel used for production and study of methane hydrates), seismic reflection imaging of methane hydrate deposits in the Arctic, molecular dynamic simulations, and computational methods for visualization. Two projects funded by DOE-FE have been implemented at ORNL.

ORNL also proposes to integrate its extensive capabilities in separations, bioengineering and biosciences, and chemical processing to create a comprehensive and accessible international resource for meeting needs in energy efficiency and pollution prevention.

Separations Science and Chemical Processing

Problems in separations and chemical processing challenge industries worldwide. 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; with good data, it is also possible to minimize engineered overcompensation and ensure more efficient use of resources and energy. Stringent requirements for purity are being placed on chemicals, pharmaceuticals, food, and materials. Many of these problems and challenges for process industries are also concerns for DOE.

Oak Ridge expertise in separations and chemical processing was initially developed to meet the challenge of purifying crude uranium and separating isotopes. Work based on separations and chemical processing has continued throughout the Laboratory's history, with activities 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 and chemical engineering, 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, advanced capabilities in process control and monitoring, and broad expertise in the management and processing of hazardous and radioactive materials.

With the most comprehensive separations capabilities in the DOE system, ORNL carries out programs ranging from fundamental research to demonstration projects, supporting programs in DOE's Office of Science (DOE-SC); Office of Nuclear Energy, Science and Technology (DOE-NE); Office of Environmental Management (DOE-EM); Office of Energy Efficiency and Renewable Energy (DOE-EE); and Office of Fossil Energy (DOE-FE). Activities involve 9 of ORNL's 16 research 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, bioprocessing, and life-cycle analysis.

ORNL is capitalizing on its assets and on industry interest in a national laboratory center for separations science and chemical processing by developing the Center for Separations and Chemical Processing (CSCP). The CSCP will coordinate ORNL's capabilities, establish collaborations with academia, and extend these capabilities to the industrial sector. The CSCP will provide an integrated program and a user center to support the U.S. chemical industry.

The CSCP builds on ORNL efforts in separations and will 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 include a user center that will build on existing separations-related user facilities: the Bioprocessing Research Facility, the High Flux Isotope Reactor, and the Physical Properties Research Facility. This effort will also expand ORNL's involvement in related computational research on chemical and physical properties and include new 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, which will be available to government, university, and industrial users, will provide a platform for testing instrumentation and computer analyses of separation systems.

Through these activities, the CSCP provides integration of diverse capabilities, creating a complete and accessible separations competency. The CSCP will maintain a DOE identity, with initial work on an environmental project for DOE-EM and DOE-FE. Subsequent initiatives will focus first on DOE-EE and then on encouraging industrial participation and support, both through collaborative 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. Working agreements in separations with leading universities are being developed. A Memorandum of Understanding has been established with the University of Texas, and discussions with the six UT-Battelle core universities are under way. Networking with other national laboratories is being pursued through the Battelle Technical Council.

The following actions have been taken:

- The Physical Properties Research Facility, with equipment for measuring thermophysical properties, is operating as a DOE national user facility.
- New capabilities and staff have been added to measure chemical and physical properties, expanding ORNL's involvement in related computational research.
- ORNL has a leadership role in DOE's separations roadmapping activities and the chemical industry's Vision 2020 research planning efforts.
- The CSCP co-director has a DOE Headquarters assignment, supporting the Chemical Industries of the Future program in DOE-EE's Office of Industrial Technologies.

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. The building will be incorporated in ORNL's plans for future site development (see Sect. 7.3). Projected funding is summarized in Table 5.3. Resources are sought from DOE-FE (Petroleum—AC), DOE-EE (Industrial Energy Conservation—ED), and DOE-SC (Basic Energy Sciences—KC). Support will also be requested from DOE-NE (Nuclear Energy R&D—AF, Isotope Production and Distribution—ST) and DOE-EM, from other agencies, and from industry sponsors.

Table 5.3
Funding projections for Separations Science and Chemical Processing by fiscal year
(in millions of dollars)

	2001	2002	2003	2004	2005	2006
DOE						
Office of Fossil Energy	2.0	2.0	2.0	2.0	2.0	2.0
Office of Energy Efficiency and Renewable Energy	0.6	0.6	1.0	1.2	1.2	1.4
Office of Science	1.7	1.9	2.0	2.0	2.0	2.1
Industry	0.7	1.0	1.5	2.0	2.0	2.0
Department of Defense	0.0	0.2	0.4	0.4	0.6	0.6
Total	**5.0**	**5.7**	**6.9**	**7.6**	**7.8**	**8.1**

5.2.3 • Nuclear Energy, Science and Technology

ORNL programs for the DOE Office of Nuclear Energy, Science and Technology (DOE-NE) include reactor technology R&D, advanced materials science, uranium enrichment technology, space power systems, and isotope production and distribution. Significant growth in these programs is expected over the next three years.

5.2.3.1 • Reactor Technology

ORNL supports DOE's initiatives to maintain nuclear energy as a component of the nation's future energy supply.

ORNL is participating in DOE-NE's Generation IV Reactor roadmapping and in assessments of gas-cooled reactor commercialization and small reactor economics. As a component of Generation IV reactor evaluations, ORNL and Sandia National Laboratories (SNL) are partnered to evaluate and propose a salt-cooled, graphite matrix–fueled Advanced High Temperature Reactor (AHTR). Using the attributes of fluoride salt coolant, the AHTR has the potential to achieve very high levels of safety by operating at very low pressure, thus avoiding many of the consequences associated with loss-of-coolant accidents. The AHTR would produce high-temperature heat, >1000°C at coolant outlet, which offers the

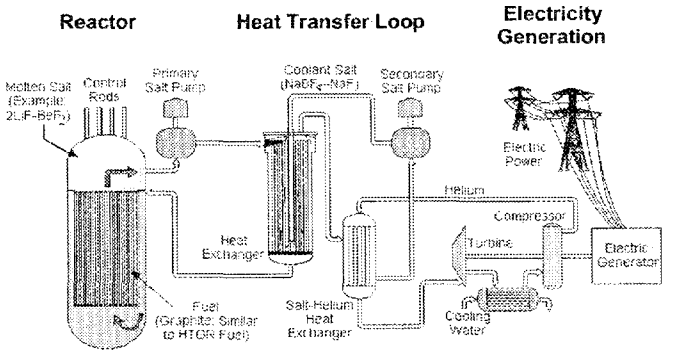

Figure 5.6
Schematic of the Advanced High-Temperature Reactor.

prospect of electricity production and thermochemical hydrogen production at very high efficiencies. The superior heat transfer properties of low-pressure salt (compared to high-pressure helium gas) are expected to allow the AHTR to operate at higher fission energy density and thus be smaller and less costly than analogous gas-cooled reactor designs (see Fig. 5.6). Reestablishment of molten salt testing facilities, such as a high-temperature flow loop for materials testing, is a near-term ORNL priority.

ORNL is also evaluating potential involvement in several industry-led advanced reactor concepts. The International Reactor Innovative and Secure (IRIS) concept is a 100- to 300-MW(e) next-generation light water reactor designed to avoid most of the initiators for severe reactor accidents. Potential ORNL roles include computational system design, reactor pressure vessel evaluations, sensors and controls, remote maintenance, and design and testing of mixed-oxide (MOX) fuel. It is possible that a first-of-a-kind IRIS could be constructed in East Tennessee, drawing on ORNL technical support.

ORNL is the lead organization for six projects funded by DOE's Nuclear Energy Research Initiative (NERI) and is participating in three NERI projects involving universities and industry. ORNL has also won four Nuclear Energy Production Optimization (NEPO) projects; two have been successfully completed, one is awaiting industry activity, and one is in progress.

5.2.3.2 • Advanced Materials

ORNL will continue its development of advanced high-temperature materials for nuclear reactors. Active fields of research include stainless steels (with a range of operating temperatures up to 800°C), refractory metals (up to 1300°C) and nuclear-grade graphites (up to 3000°C).

As part of a DOE-NE cooperative project with the laboratories of the Commissariat à l'Energie Atomique (CEA) in France, ORNL will develop and test nanocomposited oxide dispersion–strengthened ferritic steels with the potential to operate in reactor environments at temperatures 200°C higher than currently available ferritic steels. If successfully developed, these steels could permit higher temperature operation and increased safety margins for advanced reactor concepts.

Refractory metal alloy development is being performed for the Advanced Radioisotope Power Systems Programs and for the Naval Nuclear Reactors Program. Newly developed fabrication methods for molybdenum-rhenium alloys have yielded a Mo-^{43}Re alloy that is weldable and has excellent high-temperature strength properties. Future work on radiation testing of Mo-^{43}Re and development of other, more ductile Mo-Re alloys with superior thermal conductivity properties should make these alloys more useful to reactor designers.

NERI is supporting tests of the irradiation properties of ORNL's high-thermal conductivity graphite foam in order to evaluate its suitability as an in-core matrix material for high-temperature graphite reactors. Improving the thermal conductivity of nuclear graphites could allow graphite reactors to be more compact and have higher safety margins.

ORNL contributes to the DOE-NE Advanced Fuel Cycle Program (formerly the Accelerator Applications Program) with roles in the areas of advanced spallation target materials and chemical separations. ORNL's Radiochemical Engineering Development Center (REDC) has been identified as the preferred facility for future pilot-scale demonstrations of fuel reprocessing technologies and other chemical separation processes being evaluated for partitioning and transmutation of radionuclides in spent fuel.

5.2.3.3 • Advanced Fuels Accelerator Applications

The Advanced Accelerator Applications (AAA) Program is supporting the establishment of a coated-particle fuel fabrication R&D facility at ORNL beginning in FY 2002. This is envisioned as the first step in a long-term research activity. Gas-cooled reactors, such as the gas turbine modular helium reactor (GT-MHR) and the Pebble Bed Modular Reactor, use TRISO-coated particles as fuel. The initial objectives of the ORNL facility will be (1) to fabricate small quantities (i.e., gram quantities) of uranium- and plutonium-based fuel, (2) to characterize the fuel, and (3) to perform research on techniques for improving the performance and characteristics of the coated fuel. The long-term program may involve some irradiation of coated particles in HFIR with post-irradiation examination (PIE) in the Irradiated Fuels Examination Laboratory (IFEL, Building 3525).

Fabrication of coated-particle fuel, initially developed at ORNL, is a two-step process. First, the uranium or plutonium is formed into small (about 0.3-mm-diam) kernels using internal gelation techniques. Second, multiple carbide coatings are applied to the kernels in a fluidized bed configuration. The first step, gelation preparation of uranium kernels, can be accomplished in a Nuclear Science and Technology Division laboratory specifically designed for this purpose, located in the Radiochemistry Laboratory (Building 4501). The coating of uranium particles is expected to involve the procurement and installation of specialized systems in suitable space in the IFEL. Research on fabrication of plutonium-based fuels would take place in glove-box facilities in the REDC.

The AAA program will also comprise chemical separations research, including testing at Building 4501 and the REDC; irradiated materials research, including potential work at the Irradiated Materials Examination and Testing (IMET) hot cell facility (Building 3025E); and computational physics research.

5.2.3.4 • Advanced Gas Centrifuge

Gas centrifuge technology represents a major new strategic thrust for ORNL. Recent developments in the uranium enrichment marketplace have underscored the need for the United States to develop a domestic enrichment technology to replace gaseous diffusion plants. ORNL is performing engineering development and design on an advanced gas centrifuge (AGC) under a CRADA for USEC and is supporting the planning of a federally funded AGC program for DOE-NE. Advances since 1985 in high-strength lightweight materials, computational science, motor technology, and sensors appear to offer a low-risk path toward the development of a centrifuge machine capable of 325 separative work units (SWU) per year with very attractive economics. During the next several years, ORNL expects to be involved in the refurbishment of an existing test facility at the East Tennessee Technology Park and in the design, fabrication, and testing of full-scale production centrifuges.

5.2.3.5 • Advanced Radioisotope Power Systems

ORNL supports the production of parts for radioisotope power systems supplied to the National Aeronautics and Space Administration (NASA) by providing the materials processing and precision fabrication required to produce the iridium clad vent sets and the carbon-carbon holders. In a recent record of decision, DOE announced the selection of the REDC and the High Flux Isotope Reactor (HFIR) for the domestic production of ^{238}Pu for future space missions. Irradiation of ^{237}Np targets to produce 2 to 5 kg per year of ^{238}Pu will occur in the Advanced Test Reactor (ATR) at the Idaho National Engineering and Environmental Laboratory and in the HFIR at ORNL. Fabrication of the ^{237}Np targets for both ATR and HFIR irradiations would be carried out at REDC. Test irradiations are being completed, and planning for the REDC facility modifications has begun. Production of ^{238}Pu could begin as early as 2006, depending on available funding.

5.2.3.6 • Isotope-Related Programs

ORNL's Isotope 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).

The isotope ^{213}Bi, a short-lived decay product of ^{233}U, has shown promise in the treatment of acute myeloid leukemia and is being evaluated for use in treating other cancers. Small amounts of the ^{213}Bi precursor ^{225}Ac are being supplied by ORNL for clinical trials at Sloan-Kettering Memorial Cancer Center in New York. To meet a near-term DOE commitment to double the supply of ^{213}Bi, ORNL has begun additional extractions of ^{229}Th from the ^{233}U inventories stored in Building 3019 (see Sect. 5.4). Natural decay of the ^{229}Th generates ^{225}Ac, which is shipped to medical research centers for the on-site generation of ^{213}Bi. The separation of ^{229}Th is conducted in the ORNL Radioactive Materials Analytical Laboratory, and the ^{225}Ac is extracted and purified in the Radiochemical Development Laboratory. DOE plans to work with the private sector to provide a large-scale source of ^{213}Bi and has issued a request for proposals for commercial processing of ^{233}U to provide the $^{225}Ac/^{213}Bi$ supply for research and cancer therapy.

ORNL also supports DOE's Depleted Uranium Hexafluoride Program, which was transferred in FY 2001 from DOE-NE to the DOE Office of Environmental Management (see Sect. 5.3).

5.3 • Environmental Quality

Funding for science and technology (S&T) activities at ORNL that directly support DOE's environmental quality (EQ) goal—to "aggressively clean up the environmental legacy of nuclear weapons and civilian nuclear research and development programs at the Department's remaining sites, safely manage nuclear materials and spent nuclear fuel, and permanently dispose of the Nation's radioactive waste"—is provided primarily by DOE's Office of Environmental Management (DOE-EM),[1] mainly through the DOE-EM Office of Science and Technology (OST). Research supported by other DOE organizations also contributes to meeting DOE's needs in EQ.

5.3.1 • Current Activities

5.3.1.1 • Focus Areas

Tanks Focus Area

ORNL support for the Tanks Focus Area (TFA) spans technical management; waste chemistry, retrieval, and pretreatment; tank closure; and tank integrity assessment. ORNL also provides the Pretreatment Technology Integration Manager for the TFA and the End-User Steering Committee representative for Oak Ridge.

Experience gained during the removal of wastes from the primary Gunite and Associated Tanks (GAAT) at ORNL, using technologies and systems developed with OST sponsorship, is being documented and disseminated. ORNL is also assisting DOE's Hanford Site in the selection of systems for retrieval of wastes from single-shell tanks and developing enhanced grout formulation for tank closure in collaboration with the Savannah River Site (SRS).

An integrated systems approach developed at ORNL for managing waste from the Melton Valley Storage Tanks (MVSTs) incorporates state-of-the-art evaporators, a crystalline silicotitanate ion exchange system for removing cesium and strontium, and a cross-flow filtration system with dual Coriolis monitoring. Experience gained from this activity is being applied to treatment studies for tank wastes at Hanford, SRS, and the Idaho National Engineering and Environmental Laboratory (INEEL). ORNL is also involved in evaluating the MVST waste immobilization approach planned by the private vendor.

ORNL played a major role in evaluating pretreatment alternatives for the SRS Salt Processing Project (SPP), including testing and optimization of the three final alternatives. One of these alternatives, caustic side solvent extraction (CSSX), uses a novel solvent developed at ORNL with support from the

[1]The principal exception is activities related to accelerator-based systems, which are funded by DOE's Office of Nuclear Energy, Science and Technology; see Sect. 5.2.3.

Environmental Management Science Program and the DOE-EM Efficient Separations and Processing Crosscutting Program. Tests of the final alternatives in ORNL's shielded hot cells provided data that were critically important to the SPP technology selection process, which was completed in June 2001 with the selection of the CSSX process as the preferred cesium removal technology.

Tank waste chemistry work at ORNL supports Hanford and SRS. Activities include identification of waste compositions and operating envelopes to optimize treatment efficiency and predict and prevent formation of solids that can plug pipelines. ORNL proposes to expand its interactions with Hanford and INEEL in developing and demonstrating solutions to tank waste problems.

Subsurface Contaminants Focus Area

ORNL supports the Subsurface Contaminants Focus Area (SCFA) by providing a product line integrator for the Dense Non-Aqueous Phase Liquids (DNAPL) Product Line. The DNAPL Product Line Integrator is cooperating with other agencies, including the National Aeronautics and Space Administration (NASA), the Department of Defense (DOD), and the Environmental Protection Agency (EPA), to conduct *in situ* remediation technology demonstrations at Cape Canaveral. As a partner laboratory of the SCFA Lead Laboratory, ORNL provides expertise to sites and focus area management as needed.

ORNL is studying the long-term performance of *in situ* reactive barriers for contaminant removal. Activities are conducted in collaboration with other federal agencies through the Federal Remediation Technologies Roundtable and the Remediation Technologies Development Forum (RTDF). Major objectives are to develop *a priori* testing requirements to predict barrier lifetime, monitoring methods to provide early warning of incipient barrier failure, long-term monitoring protocols to minimize operation and maintenance costs, and sampling protocols and monitoring methods to evaluate barrier performance.

ORNL also collaborates with other federal agencies through the RTDF Bioremediation Consortium and the EPA Environmental Technology Verification Program, which accelerates the development and commercialization of improved technologies through independent testing, verification, and reporting. Microbial monitoring technologies applicable to natural attenuation, biostimulation, and bioaugmentation have been developed and applied at RTDF test sites and several remediation sites in the Oak Ridge area, including a carbon tetrachloride plume at the Y-12 National Security Complex.

In conjunction with the Colorado School of Mines, ORNL has conducted extensive work on *in situ* remediation of DNAPLs in low-permeability media. Field testing and demonstration activities have been conducted at the Portsmouth Gaseous Diffusion Plant, Aber Road (Cincinnati), and Sarina, Canada.

ORNL and other DOE laboratories are working to define a new EM initiative on subsurface and vadose zone science. This initiative is aimed at understanding basic subsurface processes, improving data collection and monitoring capabilities, and developing improved computer models, predictive tools, and data visualization techniques. Work in these areas will benefit from the Field Research Center established to support the Natural and Accelerated Bioremediation Research (NABIR) Program (see Sect. 5.1.2.2). ORNL plans to enhance cross-program and cross-agency collaboration and sharing of results through such initiatives to improve DOE's capabilities for remediating its environmental legacy.

Nuclear Materials Focus Area

ORNL is conducting alpha radiolysis studies for ^{233}U oxides in support of the Nuclear Materials Focus Area (NMFA). ORNL has been an active host for NMFA visits to the Oak Ridge site and has helped end users to define and document technology needs in this area. ORNL is available to contribute to the upcoming roadmapping activity for nuclear materials S&T.

Deactivation and Decommissioning Focus Area

ORNL chairs the Deactivation and Decommissioning (D&D) Focus Area (DDFA) Lead Laboratory, which also includes the Florida International University Hemispheric Center for Environmental Technology and the Electric Power Research Institute. This lead laboratory role is expected to expand to include (1) increased technical assistance and outreach to non-EM organizations that are generating relevant S&T results and (2) possible support for roadmapping activities.

Transuranic and Mixed Waste Focus Area

ORNL's primary role in the Transuranic and Mixed Waste Focus Area has been leadership of the national Mercury Working Group, which coordinates DOE-EM's mercury mixed waste treatment technology development and demonstration. As a member of the national Waste Elimination Team, ORNL is also conducting complex-wide projects to inventory and subcontract the disposition of two troublesome waste forms: radioactively contaminated pressurized gas cylinders and uranium and thorium chips.

5.3.1.2 • Crosscutting Programs

Characterization, Monitoring, and Sensor Technology Crosscutting Program

For the Characterization, Monitoring, and Sensor Technology (CMST) Crosscutting Program, ORNL is commercializing a chemical analysis automation system and deploying systems for monitoring tank waste slurries to prevent clogging of pipelines and processing equipment. ORNL is also supporting an initiative by end users at SRS and Oak Ridge to address long-term monitoring needs. The Laboratory's extensive capabilities in sensing and monitoring will be engaged to benefit DOE-EM as OST increases its attention to applied research needs (e.g., comprehensive systems that include sensors, sensor packaging and media interface, and data management). As sites move beyond active remediation, optimization of monitoring strategies to target site-specific needs and risks and to minimize the costs of long-term stewardship will become more important. ORNL's strengths in biological monitoring and ecological risk assessment will be applied to developing cost-efficient approaches that can be used in long-term stewardship programs to assess the effectiveness of remedial actions.

Efficient Separations and Processing Crosscutting Program

Activities for the Efficient Separations and Processing Crosscutting Program include developing and testing a process for removing mercury from organics and optimization of dissolution of aluminum from SRS and Hanford tank sludges. ORNL also acts as lead laboratory for this program. With OST's new emphasis on filling the applied research gap, this area is expected to grow.

Robotics Crosscutting Program

ORNL manages the Robotics Crosscutting Program (Rbx) D&D and Tank Waste Retrieval (TWR) product lines, establishing the research agenda with the DDFA and the TFA, respectively, and coordinating all Rbx D&D and TWR activities. ORNL also acts as the information and communication lead for Rbx and provides senior technical advisory support to the Rbx Headquarters program manager.

Research undertaken with Rbx sponsorship has led to significant follow-on funding of ORNL technologies from non-EM sponsors. Notably, development of technologies for advanced controls has led to work in human strength amplification, an area in which ORNL is now widely recognized as a world leader. Additional work in this area is projected.

5.3.1.3 • EM Science Program

The Environmental Management Science Program (EMSP), a collaborative initiative of DOE-EM and DOE-SC, sponsors basic research to address DOE's environmental legacy. ORNL has conducted or is conducting 29 EMSP research projects, 5 of which were renewed for a second 3-year term. Several basic research projects have applied for the next stage of support by EM's applied research program. To facilitate the transfer of their results to field applications, principal investigators for ORNL EMSP projects will expand one-on-one contacts with end users at selected sites.

EMSP projects at ORNL address a wide range of topics, such as improvements in waste separations and treatment, step-change improvements in contaminant sensing and monitoring, innovations in materials decontamination, and determination of the fate and transport of contaminants in subsurface media. EMSP investigators have been enlisted to assist the Oak Ridge cleanup program in better definition of S&T needs and to provide specific technical assistance. Expansion of such technical support will be pursued.

5.3.1.4 • Long-Term Stewardship Program

As noted in Sect. 5.3.1.2, ORNL is supporting a CMST initiative to address the long-term environmental monitoring needs of Oak Ridge and SRS end users. ORNL stands ready to assist in preparation of an S&T roadmap and in follow-on activities to implement the roadmap; our capabilities in institutional controls, monitoring and sensors, subsurface science, and biological monitoring and risk assessment should be valuable to these efforts.

5.3.1.5 • S&T for Organizations Other Than OST

ORNL is participating in a multiple-site initiative involving a partnership between the Pollution Prevention Program and OST that is being proposed for support in FY 2002. This Waste Elimination Initiative will harness the S&T expertise of the national laboratories to find ways of eliminating or drastically reducing the amount and/or toxicity of waste generated in the future.

For the DOE-EM Office of Site Closure, ORNL coordinates (1) a program of technical support for the conversion of depleted uranium hexafluoride and (2) multilaboratory R&D on safe disposition and beneficial reuse of depleted uranium, which includes projects that address the use of depleted UO_2 in spent nuclear fuel repositories, properties of heavy concrete made with uranium oxides, and catalyst and semiconductor applications of uranium oxides.

ORNL's Heavy Isotope Management Group (HIMG) provides assistance and advice on the disposition of DOE's surplus nuclear materials. This FY 2001 pilot program (part of the Nuclear Materials Stewardship Initiative) matches the heavy isotope needs of DOE sites with surplus materials at various locations. Surplus californium, curium, and certain americium isotopes at the Lawrence Livermore and Lawrence Berkeley national laboratories will be transferred to ORNL for programmatic use. A cost/benefit analysis of HIMG activities during FY 2001 will support a decision on continued funding.

ORNL also supports DOE's Nuclear Criticality Safety Program (NCSP), a cross-cutting, multilaboratory program led by the Office of the Deputy Administrator for Defense Programs with additional funding from other DOE organizations. ORNL efforts are primarily funded by DOE-EM. ORNL (1) performs the lead role in the Nuclear Data Task of the NCSP by measuring neutron cross sections with the Oak Ridge Electron Linear Accelerator (ORELA), evaluating the measured data with the SAMMY code, and testing the evaluations in conjunction with the Cross Section Evaluation Working Group; (2) coordinates the work program of the Analytical Methods Task by providing capability maintenance and training and user assistance in the SCALE/KENO code system; and (3) performs another NCSP Task, "Guidance for Applicability of Bounding Curves/Data."

5.3.1.6 • Leadership Activities

In addition to their leadership roles in S&T activities described in Sects. 5.3.1.1–5.3.1.5, ORNL staff engage in strategic planning efforts with groups such as the DOE-EM Senior Management Council Core Team (DOE-EM R&D Program Plan, EQ R&D Portfolio, EQ Gap Analysis), the DOE Strategic Laboratory Council (DOE-EM S&T Grand Challenges, EMSP, pollution prevention), and the EM core laboratories (establishing a common laboratory S&T agenda). These efforts support the Department's establishment of a consistent, integrated EM-related S&T agenda and coordinate support for and implementation of the agenda

5.3.2 • Path Forward

ORNL's goal for EQ S&T activities is to achieve modest growth despite the maturity of this program area and budget uncertainty. Key elements of our approach to achieving this goal are as follows:

1. **Expand involvement in key OST organizations.** ORNL will expand its activities in four areas:
   - D&D Focus Area. We will fulfill our lead laboratory responsibility through broadly based leadership in S&T planning and development of an interface to S&T outside DOE-EM.
   - Nuclear Materials Focus Area. New work will result from the transfer of the depleted UF_6 disposition program to DOE-EM and the need for an associated S&T component.

- Characterization, Monitoring, and Sensor Technology Crosscutting Program. ORNL has major capabilities for support of this growing program.
- Long-Term Stewardship Program. We will participate in the formative stages of this program. An S&T roadmap to be prepared in FY 2002 should indicate a critical need for S&T in areas such as institutional controls, subsurface science, and information technology.

ORNL will accomplish this goal while maintaining its present substantial involvement in tanks, subsurface contamination, efficient separations and robotics, and the EMSP.

2. **Expand EQ-related S&T programs for other organizations.** DOE-EM's need for EQ-related science far exceeds its resources. One solution to meeting this need is to leverage EQ-related science for other organizations, such as DOE-SC, DOD, EPA, and the National Science Foundation. ORNL will support this solution by sustaining and expanding its relationships with these and other organizations and by applying its strengths in the integration of basic and applied research.
3. **Contribute to the formulation and execution of a strategic EQ S&T agenda.** The DOE-EM core laboratories, including ORNL, are working to identify a few "grand challenges" that, if successfully addressed, would reduce the cleanup/stewardship mortgage while meeting applicable risk limits. An effort to address subsurface scaling issues to support defensible, enduring decisions on the need for and priority of site cleanup has been launched, and other collaborative initiatives are expected.

5.4 • National Nuclear Security

ORNL's National Security Directorate provides programmatic and organizational focus for Laboratory activities in support of DOE's National Nuclear Security business line. During the planning period, ORNL will continue to focus on growing research programs that support this vital area.

Capabilities developed to support DOE's needs are also applicable to the needs of other federal, regional, and local agencies whose responsibilities include national security, public safety, law enforcement, and other security-related issues. Efforts will be made to capitalize on synergies in these needs to expand the Laboratory's opportunities, as described in Sect. 5.6.2. The Associate Laboratory Director for National Security at ORNL searches for opportunities to apply the distinctive capabilities of the Oak Ridge Complex to the needs of DOE and other government agencies with roles in national security. The partnership between ORNL and DOE's Y-12 National Security Complex will also create a number of opportunities for combining the expertise of these two organizations to enhance the nation's safety and security.

5.4.1 • Defense Programs

ORNL's work for the Office of the Deputy Administrator for Defense Programs (DOE-NA10) within the National Nuclear Security Administration (NNSA) includes support for nuclear weapons R&D, strategic computing, and facility transition.

At the Radiochemical Engineering Development Center (REDC), ORNL prepares and encapsulates ^{252}Cf sources for shipment to DOE's Pantex site, where the sources are used for nondestructive evaluation of weapons parts. Another task is the recovery of transuranium element isotopes from targets that were once irradiated at the Savannah River Site. These heavy isotopes are purified and shipped to Los Alamos National Laboratory for use in weapons diagnostics tests.

ORNL's Radiochemical Development Facility (Building 3019A) provides shielded, safeguarded storage for the DOE inventory of separated ^{233}U. ORNL is supporting a DOE process to seek private sector participation in processing the ^{233}U inventory to expand the supply of ^{213}Bi for medical applications (see Sect. 5.2.3). Program modifications are under way to promote this commercialization initiative. Current activity at the facility involves enhancing the facility operational capability and material handling capabilities in accordance with an approved plan, *Program Management Plan for the ^{233}U Safe Storage Program at Oak Ridge National Laboratory* (ORNL/TM-2000/105/R1, April 2001). Security considerations associated with this project are discussed in Sect. 7.2.3.2.

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 Berkeley National Laboratory, Lawrence Livermore National Laboratory, Los Alamos National Laboratory, Sandia National Laboratories, 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-NA10 in the development and use of models to check cost estimates for major weapons complex facilities and assists DOE-NA10 in independent evaluations of new tritium production alternatives.

ORNL also provides ES&H support related to the cleanup of nuclear weapons manufacturing facilities and provides assistance as needed with emergency preparedness activities. ORNL's Radiation Safety Information Computational Center (RSICC) provides information and technology that contribute to the solution of problems occurring in programs for R&D, military application and stockpile support, and facility transition and technical support. The RSICC also receives funding from the DOE Office of Nuclear Energy, Science and Technology; the DOE Office of Environmental Management; the Offices of Fusion Energy Sciences and Basic Energy Sciences within the DOE Office of Science; the DOE Office of Civilian Radioactive Waste Management, the NNSA Office of the Deputy Administrator for Defense Nuclear Nonproliferation, and the Defense Special Weapons Agency. Its integration of developments in the various programs supports the information and technology needs of all scientists and engineers doing radiation transport calculations.

5.4.2 • Defense Nuclear Nonproliferation

The NNSA Office of the Deputy Administrator for Defense Nuclear Nonproliferation (DOE-NA20) supports R&D activities and technical assessments related to national security requirements. Much of this work is performed in partnership with the Y-12 National Security Complex. Activities 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.

For the Office of International Nuclear Security (NN-30), ORNL conducts activities such as developing technology and providing systems for the verification of highly enriched uranium blend-down in Russian Federation facilities.

ORNL and Y-12 participate in two efforts sponsored by the DOE-NA20 Office of Arms Control and Nonproliferation (NN-40): the Initiatives for Proliferation Prevention (IPP) and the Nuclear Cities Initiative (NCI). ORNL is working with scientists in Kazakhstan, U.S. private industry, and the Agricultural Research Service of the U.S. Department of Agriculture to develop technologies for preventing food contamination.

Under the sponsorship of the DOE-NA20 Office of Fissile Materials Disposition (NN-60), 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. Critical research at ORNL includes management of a multi-site effort to fabricate, irradiate and test plutonium-based (MOX) light water reactor fuels. Postirradiation examination of these MOX fuels is conducted at ORNL's Irradiated Fuels Examination Laboratory in Building 3525. ORNL was identified in the *Surplus Plutonium Disposition Final Environmental Impact Statement* (DOE/EIS-0283, November 1999) for future roles for postirradiation examination of commercial MOX reactor fuels.

ORNL is also managing a multilaboratory, multinational irradiation test program, named Parallax, to demonstrate the feasibility of using CANDU (Canadian deuterium-uranium) reactors for the fissioning of U.S. and Russian surplus plutonium. Co-irradiation of U.S.-origin and Russian-origin fuel has been initiated in a Canadian test reactor.

ORNL manages and conducts joint research with Russia with the objective of developing the necessary technology to fabricate MOX fuels for Russian reactors, to support the fissioning of Russian

plutonium in Russian and Ukrainian VVER-1000 pressurized water reactors. ORNL also performs design and safety analyses needed for conversion of the Russian BN-600 liquid metal–cooled reactor from a plutonium breeder to a plutonium burner and participates in the design and development of a plutonium-burning gas turbine–modular helium reactor in Russia.

Development of new technologies for detection of illicit proliferation of nuclear, chemical, and biological weapons and for domestic defense is carried out at ORNL with funding from the DOE-NA20 Office of Nonproliferation Research and Engineering (NN-20), which includes the Chemical and Biological National Security Program (CBNP).

ORNL is developing improved scintillators and other radiation-sensitive materials to increase sensitivity and enhance fieldability through research focused on new thin-film scintillation materials, doping of traditional semiconductor materials with rare earth elements to improve the electronic properties, and several other innovative approaches to detection of radiation. In the microtechnologies area, ORNL is developing "miniature" analogs of conventional chemical analysis laboratory tools to perform field monitoring and surveillance functions, through projects such as the Lab-on-a-Chip and the microchip mass spectrometer. In addition, the Laboratory is exploring innovative ORNL-developed "micro" devices, such as microcantilevers and microcalorimetric spectroscopy, to determine their applicability to nonproliferation missions.

In the nuclear materials analysis area, ORNL is spearheading a "grand challenge" program in mass spectrometry with the goal of detecting the entire signal all the time. NN-20 also funds development of forensics technology to assist with attribution; projects include extraction of maximum information from low-quality surveillance video, improved methods for collection and analysis of fingerprints, and determination of time since death (in collaboration with the University of Tennessee's forensic anthropology facility, known as the "Body Farm"). The results from this work are expected to find utility in monitoring for nuclear smuggling and terrorist activities and in monitoring for compliance with arms nuclear control treaties in international venues.

ORNL is also working on defensive measures relating to chemical and biological weapons. World-leading capabilities in mass spectrometry, Lab-on-a-Chip technology, and biobased assays are being applied to development of sensors to detect and identify chemical and biological warfare agents in order to trigger defensive action that will protect personnel and facilities in domestic/civilian venues. Much of this technology is expected to be made available to law enforcement and other civilian first-responder organizations for defense against domestic terrorist actions and for consequence management in decontaminating personnel and facilities. ORNL's National Security Directorate collaborates with the Y-12 National Security Program Office (NSPO) to develop a comprehensive Oak Ridge program in national security (see Sect. 4.6), including defense nonproliferation. The DOE program is complemented by work for other federal agencies (see Sect. 5.6) in nonproliferation and law enforcement through NSPO.

5.4.3 • Naval Nuclear Reactors

ORNL supports the NNSA Deputy Administrator for Naval Nuclear Reactors through work for DOE's Knolls Atomic Power Laboratory and Bettis Atomic Power Laboratory. Activities include testing and characterization of advanced high-temperature structural materials and of molten fluoride salts. ORNL also performs chemical analyses of samples of irradiated fuels and develops specialized computational physics methods.

5.5 • Other DOE Programs

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

ORNL provides support to the DOE Office of Environment, Safety and Health in the categories of oversight, policy and standards, technical assistance, health studies, and information resource manage-

ment. R&D and technical support activities span several ORNL divisions and organizations. Activities include technical standards, criticality safety analysis, performance indicators, occurrence reporting quality, environmental policy and assistance, National Environmental Policy Act (NEPA) compliance, occupational safety and health, facility disposition safety and health support, epidemiology and health surveillance, and business performance systems.

Work for the Office of Policy 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 also provides support to the Office of International Affairs, which is engaged in building coalitions in support of U.S. foreign energy policy.

ORNL conducts R&D for DOE's Office of Intelligence through Memoranda of Understanding (MOUs) with the National Security Programs Office of the Y-12 National Security Complex.

ORNL supports the Federal Energy Regulatory Commission (FERC) in (1) environmental, economic, and engineering assessments that support licensing of nonfederal hydroelectric projects; (2) studies related to compliance with FERC license conditions or other environmental regulations at existing projects; and (3) technical assistance in other related areas, such as headwater benefits analysis and hydropower benefits in the control of greenhouse gas emissions. 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.

5.6 • Work for Other Sponsors

5.6.1 • Overview

The DOE national laboratories can apply their resources and skills to the specific needs of other federal agencies and other customers (including public/private corporations, industry, and colleges and universities) through DOE's Work for Others (WFO) Program. WFO projects are typically performed at a laboratory on a full cost recovery basis, must support the missions of DOE and the individual laboratory, and may not compete directly with capabilities available in the U.S. domestic private sector.

ORNL carries out a number of projects for other sponsors, including the U.S. Nuclear Regulatory Commission (NRC), the U.S. Department of Defense (DOD), the U.S. Department of Transportation (DOT), the National Aeronautics and Space Administration (NASA), the U.S. Environmental Protection Agency (EPA), the U.S. Department of Health and Human Services (DHHS), the Federal Emergency Management Agency (FEMA), the National Science Foundation (NSF), and the Electric Power Research Institute. Detailed descriptions of current projects are provided in the Supplemental Information appended to this report. In addition, WFO projects for a variety of national security customers are performed through mechanisms established and administered by DOE's Office of Intelligence (DOE-IN).

This work serves to broaden ORNL's customer base and provides opportunities for partnerships with universities, industry, other DOE laboratories, other federal agencies, and state and regional organizations. It also benefits the Laboratory's technical staff by providing opportunities to understand the needs of ORNL's customers and markets. Observation of the latest trends and breakthroughs from other technical organizations and the lessons learned by others makes it possible for ORNL to improve its own technologies and leverage its expertise with that of other institutions, integrating practical experience with the Laboratory's demonstrated R&D capabilities.

WFO projects often draw on the resources available at other DOE facilities, notably the Advanced Technologies organization of DOE's Y-12 National Security Complex through ORNL's National Security Directorate (see Sect. 5.4). Staff also work closely with the DOE Oak Ridge Operations Office

(DOE-ORO) Office of Partnerships and Program Development and with DOE's Y-12 Area Office (YAO).

Development of new WFO programs is carried out by individual researchers, by program development staff within ORNL divisions and directorates, and by ORNL senior managers. The Technology Transfer and Economic Development Directorate (see Sect. 8.1) assists in the development of new programs and provides key services dealing with intellectual property and partnerships.

During the planning period, ORNL will seek to broaden its work for non-DOE sponsors in several key areas. Efforts will focus 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, with an emphasis on emerging areas such as gene function and biotechnology and pressing national concerns such as national safety and security (with a particular focus on information operations and weapons of mass destruction or mass effect), transportation, and environmental protection. Areas of emphasis are discussed in Sect. 5.6.2.

5.6.2 • Areas of Emphasis

5.6.2.1 • Defense-Related Programs

Our new National Security Initiative (see Sect. 4.6) outlines the key areas in which we will move forward in the development of science and technology to address defense-related challenges. Efforts in defense-related WFO will complement our work for the National Nuclear Security Administration (NNSA) and other DOE organizations with roles in national safety and security.

The ORNL National Security Directorate combines Laboratory resources with the capabilities of the Advanced Technologies organization (AT) at the Y-12 National Security Complex. AT comprises several business units that apply the distinctive capabilities of the Oak Ridge Complex to the needs of DOE and other government agencies and organizations with roles in national security. AT also has established relationships with several Fortune 500 corporations that build systems and components for these agencies and organizations.

Among the many unique characteristics of the Oak Ridge Complex is the ability to combine intellectual talent and expertise with advanced scientific and manufacturing equipment and material in carrying out the basic and applied R&D needed to design, manufacture, and build prototypes. Support for these efforts is provided through the Oak Ridge Centers for Manufacturing Technology and the National Prototype Center, both of which are organizationally part of AT. Unique manufacturing facilities can be used by sponsors to prototype or develop new systems and components; modify, miniaturize, or improve current systems and components; or solve problems and challenges associated with aging but vital legacy systems. The ORNL National Security Directorate is uniquely positioned and qualified to identify and integrate technologies and expertise in support of national, regional, and local agencies involved with public safety, law enforcement, and other security-related issues.

Partnerships with the National Transportation Research Center (see Sect. 5.2.1), the Tri-Lateral Alliance (see Sect. 5.6.2.2), the Law Enforcement Innovation Center (see Sect. 4.6.3), and other organizations will support activities in these areas. The Minority Educational Institutions Technology Partnerships Program (MEITP), an element of AT, cultivates long-term, mutually beneficial relationships with minority educational institutions (MEIs) that result in cooperative research, educational, and economic ventures.

U.S. Department of Defense

ORNL's work for the U.S. Department of Defense (DOD) focuses on the science and technology challenges involved in DOD's work to envision, design, prototype, model, and build the systems, platforms, and machines required to defend the nation's vital interests and protect the lives of the members of its armed forces in the 21st century. The ORNL National Security Directorate is positioned to harness the capabilities and expertise in Oak Ridge to that purpose.

Ongoing programs include (1) assessment of advanced technology applicable to future combat systems for the U.S. Army and the U.S. Marine Corps; (2) development of advanced materials for improving the structure, reducing the weight, and enhancing the protection of crew and survivability of ground vehicles, helicopters, and other aircraft; (3) development and refinement of instrumentation and sensors for detecting nuclear/biological/chemical agents and material, unexploded ordnance (UXO), and cyber security and information operations and for performing predictive diagnostics on weapons systems and vehicles; (4) analysis tools, techniques, and practices for environmental compliance, cleanup, and management of military installations and property and for safe dismantling and decommissioning of weapons systems; (5) power systems for future vehicles, facilities, and weapons systems; (6) automotive technology for the 21st Century Truck Partnership that links DOD, DOE, the Department of Transportation, and the Environmental Protection Agency with truck and power train manufacturers and with colleges and universities; and (7) modeling and simulation for transportation logistics, operational and contingency planning, information security, and the effects of weapons of mass destruction.

During the planning period, we will build on these existing programs and pursue the development of programs in several new science and technology areas that present challenges to DOD:

- homeland security R&D;
- advanced propulsion technologies for military systems/weapons;
- technologies and systems to support the Ballistic Missile Defense Organization;
- hazardous materials packaging for the military;
- information technologies to detect, identify, track and address cyber/information threats;
- asymmetric warfare threats, systems, and practices;
- nonlethal weapons technologies and systems;
- logistics modeling and technology enhancements/upgrades to reduce the logistics demand in military operations;
- hybrid electric/diesel and fuel cell technologies for military and commercial vehicles;
- advanced medical devices and shelters; and
- systems and infrastructure architectures to support the Army's development of the Interim Brigade Combat Team/Objective Force.

We also plan to establish Oak Ridge as a location for the U.S. Army's Training With Industry Program, increase our role as a technology resource for senior DOD officials; and assist the various DOD S&T offices in the preparation, execution, and analysis of experiments, technology demonstrations, equipment performance, etc. Working through the DOE Office of Intelligence, we will respond to the needs of the intelligence community.

We will continue and expand our Needs Assessment Technology Applications Team (NATAT) activity, which combines ORNL and Y-12 expertise in project management, infrastructure engineering, and systems modeling to support military installation commanders and staff. By leveraging technology that has already been developed, NATAT reviews provide installations with the tools and capabilities to reduce or avoid costs and reclaim the savings to improve training resources and overall quality of life. This program also provides a conduit for the introduction of new science and technology developments to the military and other government agencies. In support of this activity, the ORNL National Security Directorate is sponsoring the development of sensors for monitoring wells that provide continuous updates on any contaminants through wireless telemetry. These sensors are expected to significantly reduce monitoring costs throughout DOD when fully developed.

Defense Advanced Research Projects Agency

The Defense Advanced Research Projects Agency (DARPA) was established by Congress to focus on advanced research for the development of high-risk, high-payoff technologies. DARPA is recognized as the DOD lead for initiating new projects that require the application of cutting-edge technologies to solve the most difficult problems.

The organization is made up of seven offices: three that focus on the development of basic science and advanced technologies and four that address systems development and the transition of technologies

to DOD applications. The technology needs of these offices are well matched with ORNL's expertise and capabilities, spanning such areas as

- materials science and materials processing,
- measurements and control systems,
- robotics and systems integration,
- biotechnology,
- computational mathematics and physics,
- information systems, data management, and analysis,
- design and manufacturing, and
- energy and environmentally related technologies.

A sustained five-year effort at ORNL to identify R&D program opportunities with DARPA has resulted in an average of nearly 20 different DARPA-funded projects at the Laboratory for each of the last two years. During the planning period, we will continue this effort by increasing our interactions and presence at DARPA. Our objective is to provide ORNL researchers with timely, thorough information about future DARPA opportunities and to position ORNL for success with these new opportunities.

Army Transformation and Future Combat Systems

The Secretary of the Army is undertaking an aggressive plan to transform and modernize the Army to defend against rapidly changing world threats. Future enemies will be increasingly sophisticated and agile, will make extensive use of information warfare and other advanced technologies, and will choose to confront our forces in urban and complex environments. In recognition of these trends, the Army has initiated a major initiative to rapidly modernize existing forces while developing a revolutionary force called the Future Combat System (FCS) and the Objective Force Warrior that will be fielded in the next 8 to 12 years (see Fig. 5.7).

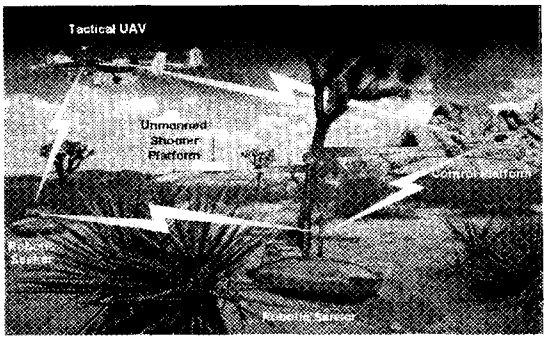

Figure 5.7
Elements of the Future Combat System.

Oak Ridge supports this initiative in several ways. A multilaboratory activity led by ORNL identified DOE technologies of potential use in developing the FCS. DOE investments in advanced materials, robotics, power systems, communications, modeling and simulation, and other technologies were reviewed with Army and DARPA representatives. Oak Ridge continues to support the FCS initiative by providing technology reviews and updates for the Army Assistant Secretary for Research, Acquisition, and Logistics and the Deputy Chief of Staff for Programs.

In related work, we are collaborating with other national laboratories to develop and test modeling and simulation tools and techniques for helping DARPA and the Army evaluate innovative concepts and conduct technology trade-offs for the FCS Program. Oak Ridge will continue to expand its support to the Army transformation initiatives during the planning period. We will also seek to support the other services as they modernize their forces to meet changing world conditions.

Land Mines and Unexploded Ordnance

We continue to develop and test improved technologies and methods for safely detecting land mines and unexploded ordnance (UXO). These programs support the military countermine, humanitarian demining, and environmental remediation efforts of DOD, DOE, and other agencies. Oak Ridge has developed several novel methods for large-area land mine and UXO detection. Work sponsored by the Strategic Environmental R&D Program/Environmental Security Technology Certification Program, the Army Corps of Engineers, the Defense Threat Reduction Agency, the Army Environmental Center, and other agencies has produced remote sensing systems that operate from aerial platforms (see Fig. 5.8).

These systems use high-resolution multispectral sensor arrays and data analysis techniques to identify buried ordnance. Other techniques include the use of chemical and biological detection systems such as microcantilevers, mass spectrometry, or genetically engineered bacteria to locate mines, ordnance, or concealed explosives. These technologies show considerable promise for safer detection of hazardous materials commonly found on active or inactive military ranges or at critical facilities in the U.S. and overseas. ORNL collaborates extensively with other federal and international agencies, universities, and industry in performing these programs.

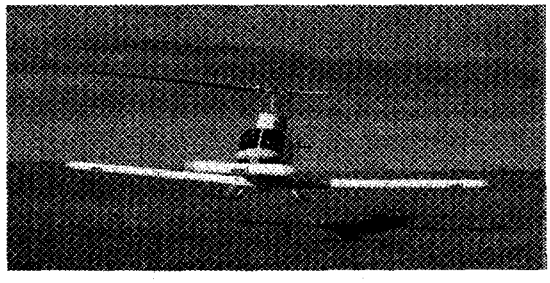

Figure 5.8
Airborne magnetometer system for sensing of unexploded ordnance.

Cyber Security

Cyber security and information assurance are of growing concern throughout the public and private sectors. As cyber threats increases in both volume and sophistication, federal agencies are challenged to maintain protection measures that keep pace with the rate of change. Information systems on which organizations depend are vulnerable to advances in technology and to actions by groups or entities with interests contrary to those of the United States. Incident information analysis and the development of countermeasures are needed to support detection and response with minimal or no human intervention and to reduce vulnerabilities to disruptions, data tampering, fraud and inappropriate disclosure. ORNL will expand its involvement in the development and application of technologies to combat these growing threats through its National Security Initiative (see Sect. 4.6).

National Safety and Security

ORNL continues to support the National Institute of Justice, the Federal Bureau of Investigation, and law enforcement agencies with its expertise in chemistry, biology, and computing. Applied R&D for emergency planning capabilities and products is conducted for agencies such as the Federal Emergency Management Agency, the Department of the Army, the U.S. Environmental Protection Agency, and the National Weather Service. ORNL also has substantial expertise in emergency management and will continue working to integrate and apply Oak Ridge Complex capabilities for addressing both natural and man-made disasters.

5.6.2.2 • Aerospace R&D and Technology

ORNL's commitment to securing new roles in aerospace R&D and technology, building on the ongoing programs described in the Supplemental Information appended to this report, is facilitated by Memoranda of Understanding (MOUs) established by DOE-ORO, linking DOE's Oak Ridge facilities to the National Aeronautics and Space Administration (NASA) George C. Marshall Space Flight Center in Huntsville, Alabama, and the U.S. Air Force Arnold Engineering Development Center near Tullahoma, Tennessee. Through this Tri-Lateral Alliance, collaborations will be pursued in such areas as advanced materials and material processes, environmental technology, remote sensing, robotics, space-based global change observation, space launch, and transportation.

ORNL is also working with the Human Exploration and Development of Space (HEDS) enterprise (formerly, the Space Exploration Program) at the NASA Johnson Space Center in Houston, Texas. HEDS is engaged in planning to define a technology development program for missions beyond low earth orbit that could be accomplished early in the 21st century. Through a small program development initiative, ORNL is providing support to HEDS in its assessment of technological requirements for a future space exploration program. Work is under way to identify applicable ORNL capabilities that meet NASA's needs (e.g., lightweight, high-strength materials; power management systems; advanced computing; advanced instrumentation; and robotics) and to build relationships between key technical

staff members at the Johnson Space Center and ORNL. Over the next two to three years, specific areas of technical support will be identified and a program of support will be initiated.

5.6.2.3 • Health-Related Programs

DOE's mission needs include information about the health effects of legacy environmental wastes, future energy technologies, and chemical and biological weapons. ORNL's programs to address these needs, coupled with its extensive capabilities and expertise in biological and medical science and technology, position the Laboratory to expand its health-related work for other sponsors.

Two emerging efforts, the biomedical engineering and bioengineering program described in Sect. 5.1.2.1 and the Virtual Human (VH) project, are expected to support the needs of federal agencies and the private sector. A number of ongoing programs and collaborations with other national laboratories, academic institutions, medical centers, and industrial partners, including those that support the Complex Biological Systems Initiative (see Sect. 4.2), also offer opportunities for new or expanded efforts to address health-related needs.

VH is a human simulation tool, under development at ORNL, that provides a research/testing environment comprising an integrated system of biophysical and other models, data and advanced computational algorithms, and a computational (engineering) solid-body model of human anatomy. A Web-based interface supports easy, rapid access from several points of entry. VH will serve as a platform for investigating human biological and physical responses to biological, chemical, or physical stimuli.

VH can provide multiple new capabilities to both military and civilian sectors. For example, VH will support evaluations of the effectiveness and safety of nonlethal technologies and the effectiveness of advanced clothing and armor. VH will also make it possible to simulate training scenarios involving new equipment and methods and to test vehicle designs for safety. Potential biomedical applications include prosthesis design, evaluation of microgravity effects, personal medical informatics for diagnosis, patient education, and therapeutics selection.

ORNL is uniquely equipped to develop the VH because of its experience with anatomical and biokinetic models, its databases, its informatics and visualization capabilities, and its access to the supercomputers and massive data storage devices required to address this problem. Given the technical scope and multidisciplinary nature of this effort, however, other organizations have much to contribute to VH development, from supplying user requirements to contributing technical development of physiological models, and ORNL has developed collaborations with a variety of other research institutions.

Interest in VH has been expressed by the Department of Health and Human Services [through the National Library of Medicine, the National Cancer Institute, and the National Institutes of Health (NIH)], the Department of Defense, the Federal Bureau of Investigation, and the Department of Transportation's National Highway Traffic Safety Administration. A proposal has been submitted to the NIH Biomedical Information Science and Technology Initiative (BISTI).

5.6.2.4 • Transportation-Related Programs

Challenges

The transportation sector presents a wide variety of challenges that span energy resources, environmental quality, national security, economic growth, and quality of life. These challenges include the following issues:

- In 1999, the transportation area accounted for about 28% of the nation's energy use and about two-thirds of its oil consumption. More than 97% of the fuel consumed by the U.S. transportation sector is petroleum-based.
- Imports of petroleum (almost $67 billion in 1999) and of automotive vehicles, engines, and parts ($180 billion in 1999) account for 24% of U.S. goods imports.

- The General Accounting Office (GAO) estimates the military cost of U.S. dependence on imported oil to be $3.3 billion per year. The total cost of this dependence since 1970 is estimated at $7 trillion (in 1998 dollars).
- The demand for transportation energy is projected to grow at an annual rate of 1.8%, to 38.5 quadrillion Btu in 2020, 1.0 quadrillion Btu higher than in 2000.
- Transportation is the source of about one-third of the total U.S. carbon dioxide emissions, approaching 500 million metric tons of carbon in 1998.
- Despite major improvements in emission rates over the past two decades, transportation continues to be the primary source of air pollutants such as carbon monoxide, nitrogen oxides, and volatile organic compounds (VOCs).
- The average American household devotes 18 cents out of every dollar to transportation. Most American families spend more on driving than on health care, education, or food. Some poor families spend more than one-third of their income on transportation.
- In the last 30 years, there has been a 131% increase in vehicle miles traveled, but highway capacity has grown by only 5.7%. Increased driving has crowded the roads with the equivalent of an additional 70 million drivers. As a result, Americans will spend 7 billion hours in traffic jams in 2005 (more than 5 times the amount of time wasted in 1985).
- Aggressive driving incidents (in which an angry driver tried to kill or injure another driver after a traffic dispute) have risen by 51% since 1990. In the United States, an average of 1,500 persons are injured or killed each year as a result of aggressive driving, which may be triggered by traffic congestion.
- Congestion in air travel has also dramatically increased. During the first 9 months of 2000, 1 of every 4 flights was canceled, delayed, or diverted, affecting 119 million passengers. A projected increase in the number of airline passengers from more than 600 million in 2000 to more than 900 million in 2010 will further strain the nation's air transportation systems.

Resources

ORNL will continue to extend the application of its capabilities in transportation R&D and technology through activities that capitalize on the synergies of multiple sponsors and industrial partners. These activities will build on and enhance our DOE-funded transportation programs (see Sect. 5.2.1).

The National Transportation Research Center will be a key resource for expansion of transportation-related programs during the planning period. The NTRC was created to expand transportation R&D at ORNL and The University of Tennessee (UT), with a focus on responding to the needs of industry as well as the Federal and state governments. It brings together a number of separate R&D efforts to achieve better synergy and operating efficiency for both sponsors and performers. Particular emphasis is placed on establishing mutually beneficial partnerships between industry, universities, and government, and on providing access to unique R&D facilities that are not readily available to industry or other organizations. The NTRC is also an economic development effort involving DOE, UT-Battelle, UT, and the Development Corporation of Knox County (TDC), as discussed in Sect. 8.1.2 of the Institutional Plan.

The NTRC, operated and staffed jointly by ORNL and the University of Tennessee with special participation by private industry representatives, provides the public and private sectors with state-of-the-art knowledge, understanding, facilities, and technologies for the development and deployment of cost-effective, advanced transportation systems. To facilitate access by industry and other users, a 501(c)(3) not-for-profit corporation, called NTRC, Inc., has been formed by UT-Battelle, UT, and TDC. Its major purposes are scientific, charitable, and educational. Its goal is to stimulate and promote R&D of transportation-related technology in support of industry and other sectors of the economy that depends heavily on affordable transportation. The focus is on improving the safety, efficiency, and environmental quality of transportation systems that will help sustain economic growth.

The NTRC facility houses approximately 180 research and support personnel and comprises 11 specialized transportation research laboratories:

- **Advanced Supply Chain Management Laboratory**. Investigates the use of radio-frequency identification tags to aid in the tracking and control of hazardous materials shipments.
- **Commercial Vehicle Operations Laboratory**. Analyzes equipment and technologies for making commercial vehicles safer and more efficient.
- **Composite Materials Laboratory**. Conducts controlled, programmable analysis of the deformation and failure response of composite automotive components in relation to impact velocity.
- Defense Transportation and Logistics Laboratory. Provides analytical and operational support to the defense transportation community through development of innovative, practical tools and techniques for the analysis and management of transportation and logistics systems.
- Fuels, Engines, and Emissions Research Center. Analyzes power plant and vehicle performance and emissions reduction technologies.
- **Geographic Information Systems Laboratory**. Develops innovative ways to plan, manage, and track information using geography-based decision support systems.
- Infrastructure Materials Laboratory. Tests materials such as concrete and asphalt that are used in bridges, culverts, highways, and roadbeds.
- **Intelligent Transportation Systems Laboratory**. Provides an advanced real-world environment for evaluating and applying Intelligent Transportation Systems technologies to improve the efficiency, productivity, and safety of transportation facilities and to alleviate the impact of transportation on the environment.
- **Packaging Research Laboratory**. Helps clients develop safe, efficient, economical solutions for the shipment of hazardous and high-value materials.
- Photonics and Fiber Optics Laboratory. Conducts research on a wide range of applications, focusing primarily on remote sensing and weigh-in-motion, spectroscopy, full-spectrum solar energy, and sensors.
- **Power Electronics and Electric Machinery Research Center**. Develops and prototypes the next generation of cost-effective converters, adjustable-speed drives, electric utility and distributed-generation applications, motor controls, and efficient, compact electric machines.

Within the NTRC facility, a new center—the Heavy Vehicle Safety Research Center (HVSRC)—is being established. The HVSRC is the first new major initiative to come out of the NTRC. The HVSRC will be a national asset for the study and resolution of issues associated with the safety of heavy vehicle transportation. It will serve as a research center in which government and industry can work closely together to enhance the safety of heavy vehicles operating on our nation's highways and contribute to meeting national goals to reduce truck-related fatalities while maintaining and enhancing the economic viability of the U.S. trucking industry. Funding for FY 2002 for the HVSRC is coming as a $1 million grant from the Federal Highway Administration's Office of Safety. Support from other sources includes capital equipment funds from the NTRC and funding from DOE's Office of Heavy Vehicle Technology.

The concept for a HVSRC was included as part of the proposal that UT-Battelle prepared for the management of ORNL. Since April 2000, ORNL and Battelle Columbus have had significant interactions with federal agencies (DOT, DOE, and DOD) as well as private industry to refine the concept and to identify its initial thrust. Efforts during the first year will focus on integrated brake systems safety research. Other areas of interest, which may be addressed in the future as the HVSRC grows, include Safety Impacts of Energy Efficiency Technologies (e.g., aerodynamics), Safety Impacts of Driver-in-the-Loop Technologies (e.g., driver work load/attention), and Safety Impacts of Infrastructure (e.g., work zone, congestion, regulation). During the first year, consideration will also be given to building one or more new research capabilities at the NTRC. These capabilities include test cells for a four-wheel chassis dynamometer, a brake material characterization dynamometer, and an 80-ft flat-plate performance-based brake tester.

The HVSRC will do the following:

- build on the significant heavy vehicle research expertise of the NTRC/ORNL, Battelle Columbus, and UT;
- draw on the expertise of other Battelle family laboratories (NREL, PNNL, BNL);

- perform both basic and applied vehicle safety research for government, private industry, and joint government/industry consortia;
- undertake research on heavy vehicle safety challenges of national and strategic importance;
- provide unique research capabilities to solve critical heavy vehicle safety problems;
- form strategic partnerships to bring together, utilize, and coordinate existing research capabilities throughout the United States; and
- conduct research that supports national programs and initiatives, such as the Intelligent Vehicle Initiative (IVI), the 21st Century Truck Partnership (21CTP), and the Future Combat System (FCS).

Funding for the HVSRC will increase to $5 million per year in FY 2005.

The ORNL Center for Transportation Analysis (CTA) conducts innovative, cost-effective R&D on transportation energy and environmental issues, national transportation planning and policy, transportation systems engineering, and military transportation and logistics. CTA focuses on multimodal national and international transportation systems. Sponsors include DOE, DOD, DOT, the Environmental Protection Agency, the Department of Commerce, and the Bureau of the Census.

Programs conducted by the CTA span eight broad areas:

- Defense transportation
- Emergency management
- Intelligent transportation systems
- Logistics and supply chain management
- Statistics and data analysis
- Transportation energy and environmental policy
- Transportation materials
- Transportation planning and systems analysis

Focus Areas

During the planning period, ORNL will continue to integrate its extensive capabilities in transportation R&D and technology and apply them to a variety of challenges facing stakeholders in the transportation sector. Through the NTRC, we will focus on four key areas.

- Advanced vehicle propulsion systems. The nation needs advanced propulsion technology to replace petroleum-based energy and eliminate or minimize harmful emissions. We will emphasize partnerships with industry that lead to the development of alternative fuel vehicles including hybrid electric and fuel cell systems. We will also develop systems to make conventional propulsion technology, such as diesel systems, more environmentally acceptable.
- Traffic congestion mitigation. Congestion of the nation's highways, airports, and seaports not only increases energy consumption; it also threatens continued economic growth. It can lead to economic loss (time in congestion), social problems (road rage, air rage), and clashes between competing resource users (e.g., waterfront development vs port expansion). We will work with government and private industry sponsors to develop solutions that increase traffic flow capacity, provide timely congestion information to travelers, and optimize the use of the nation's airways, airports, waterways, and seaports.
- Transportation modeling and simulation. Proposed technology solutions should be assessed to determine their impact on transportation systems. ORNL and UT will apply their the long-term experience in modeling and simulation to work with private industry in evaluating and predicting how new technology will relieve congestion, improve fuel efficiency, reduce pollution, or otherwise alleviate transportation problems.
- Heavy vehicle safety. Heavy vehicles of all types that travel the nation's highways, railways, airways, and waterways form the backbone of our economy. The use of our transportation infrastructure by these large and cumbersome vehicles and an even larger number of personal vehicles raises a number of safety concerns. We plan to team with the commercial shipping industry and regulatory agencies to develop technologies that will lead to safer vehicles, fewer accidents, lower insurance and damage claims, and lower operating costs, as well as increasing public confidence in the safety of travel.

5.7 • Laboratory Directed R&D Program

Through its Laboratory Directed R&D (LDRD) Program, ORNL 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.

The program operates under the authority of DOE Order 413.2A, "Laboratory Directed Research and Development" (January 8, 2001). It is funded by DOE through an overhead charge to all other Laboratory programs. The annual program plan for the LDRD Program, which is prepared and submitted to DOE-SC in accordance with DOE Order 413.2, serves to request LDRD funding for the Laboratory and to provide a general description of and justification for the program. The *ORNL Laboratory Directed Research and Development Program: Annual Report to the Department of Energy Summarizing Fiscal Year 2000* (ORNL/PPA-2001/1, March 2001) provides a program overview, funding summaries, and project summaries for the LDRD Program.

ORNL uses the LDRD Program as a means of funding activities that are expected to enhance the Laboratory's capabilities for carrying out DOE missions. The program has two components: the Seed Money Fund, which supports small projects, and the Director's R&D Fund, which supports larger projects that address specific research areas. In requesting proposals for FY 2002 Director's R&D funds, the UT-Battelle Leadership Team selected research topics associated with the major Laboratory initiatives (see Sect. 4). The selection of these topics reflects ORNL's commitment to managing discretionary resources for strategic change.

Advanced Scientific Computing. New computational tools and codes are needed to enable the creation of realistic simulations of physical situations and to provide new insights into a host of scientific problems. Research, development, and deployment of mathematical models, computational methods, numerical libraries, and scientific codes are needed to take full advantage of the capabilities of ORNL's terascale computers for strategic or critical problems in materials sciences, chemistry, combustion, accelerator design, high-energy physics, nuclear physics, fusion, biology, and global systems. In addition, within the next 5 to 10 years computers 1,000 as fast as today's computers, comprising from 10,000 to 1000,000 processors, will become available. There is little understanding of how to manage or run such large systems or of how applications can exploit such architectures. To ready ORNL for these large systems, we will develop the needed expertise and experience through early involvement in the design and development process. Proposals are sought in the areas of superscalable algorithms, petascale data analysis, and mathematics and algorithms.

Complex Biological Systems: Taking Genomics to the Next Level. ORNL is developing a significant program in complex biological systems that builds on established programs and expertise in the life and environmental sciences, chemical and analytical sciences, instrumentation sciences, and computational sciences. This initiative uses innovative applications of computational, physical, chemical, and engineering sciences to biology and special facilities and resources in analytical technologies. It engages organizations and disciplines across the Laboratory such as genetic modeling (of organisms including microbes, mice, and zebrafish), biological mass spectroscopy, structural biology, protein biochemistry, computational biology, computer science, and toxicogenomics. Proposals to this initiative should address one or more of the following research areas, each of which relates directly to building a capability to address the new DOE initiative, Genomes To Life (GTL): identifying the molecular machines of life, characterizing gene regulatory networks, characterizing and understanding the functional behavior of natural microbial communities, and developing computational capabilities to understand and predict the behavior of complex biological systems.

Energy and Environmental Systems of the Future. Demands for energy throughout the world are increasing, while there is a growing realization that the resources and technology systems meeting a very large proportion of current energy needs are nonsustainable. Thus, ways to increase the availability of energy, safely and affordably, while shifting to significantly different energy paths with minimal effects on human health and the environment, will be required. Making this shift will require a thorough understanding of a broad range of science, technology, economic drivers, and policy issues that will drive the

development of future energy systems. ORNL seeks to build new R&D capabilities for the development of new energy services that are environmentally responsible and economically competitive. Proposals are sought in four areas: energy efficiency; clean power; carbon sequestration and separation sciences; measurement sciences, and integrated assessment.

Nanoscale Science, Engineering, and Technology. Leadership in nanoscale science, engineering, and technology (NSET) is essential to the future competitiveness of ORNL in broad areas of science and technology. NSET provides breakthrough opportunities in many fields central to DOE's missions, including materials science, biotechnology, processing science, energy, environmental technology, information technology, and national security. A high priority for NSET investment at ORNL is the development of capabilities for the controlled synthesis of nanomaterials and nanostructures, resulting in functionality for nanosystems. Proposals are sought in this area and in discovery and development of novel phenomena for nanotechnology; optical, magnetic, and electrical transport and coupling phenomena; nanoelectronics, quantum devices, and sensors; quantum computing and information systems; computational nanoscience; nanomechanics and nanofluidics; nanobioengineering and biotechnology; and nanosensors and applications

Neutron Sciences. The Spallation Neutron Source (SNS) and the upgrades at the High Flux Isotope Reactor (HFIR) that will be completed as part of the major Laboratory initiative in neutron sciences (see Sect. 4.1) offer a unique opportunity for ORNL and the nation to demonstrate world leadership in this area. The success of these projects (and their impact on ORNL) depends critically on the ability to develop the full potential of these new scientific tools and to integrate neutron sciences into research programs across the Laboratory. This target area focuses on five research themes that are essential to leadership in neutron sciences: novel applications of neutron scattering, neutron physics, advanced neutron optics, data visualization and analysis, and novel instrumentation concepts.

6 • R&D Partnerships and Collaborations

Research and development (R&D) partnerships with other laboratories and with universities, industry, other government agencies, and international research institutions are carried out at the Oak Ridge National Laboratory (ORNL) through traditional collaborative arrangements and increasingly through the development and application of capabilities that facilitate collaboration among geographically separated researchers, or "science at a distance." These partnerships strengthen the nation's science base and are a key element in the UT-Battelle commitment to excellence in community service. Table 6.1 lists a number of major partnerships and collaborations.

Although it is formally a national laboratory, ORNL has a strong role as an *international* laboratory, routinely hosting guest researchers and visitors from other nations. These kinds of partnerships facilitate access to facilities in other nations by U.S. scientists and encourage the globalization of science. In addition, 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 2000, ORNL hosted approximately 4000 scientists and engineers from universities, industries, and other research institutions. About 25% were industrial guests. Many conducted R&D at one of ORNL's designated user facilities.

UT-Battelle is working to expand the use of partnerships as a means for conducting collaborative R&D, facilitating access to ORNL's distinctive capabilities, improving the utilization of its scientific facilities, transferring technology to industry, and supporting the education of the next generation of scientists and engineers. UT-Battelle, itself a partnership, comprises several key resources for this expansion: the University of Tennessee (UT), a Carnegie Research Level I institution that attracts nearly $80 million annually for sponsored research programs; six "core universities," Duke University, the Georgia Institute of Technology, Florida State University, North Carolina State University, the University of Virginia, and Virginia Polytechnic Institute and State University (Virginia Tech); and Oak Ridge Associated Universities (ORAU), a consortium of 86 colleges and universities that manages the Oak Ridge Institute for Science and Education for the U.S. Department of Energy (DOE) and promotes collaborative partnerships for the benefit of its member institutions.

These resources are a key to the University Partnerships Initiative that is included in the Laboratory Agenda (see Sect. 3.2). Plans also include the following actions:

- Extend collaborative relationships with other DOE laboratories and facilities, integrating the complementary capabilities distributed across the DOE complex in support of the Department's missions.
- Build new educational, training, and research partnerships with other federal agencies; with educational consortia and museums, both regionally and nationally; and with private-sector institutions.
- Develop industry partnerships that bring the Laboratory's resources to bear on industrial problems and strengthen the economy by bringing new technologies to the marketplace.

6.1 • Laboratory Partnerships

ORNL actively supports the DOE "system of labs" approach and is engaged in numerous collaborative relationships with other national laboratories, as indicated in Table 6.1. Most notable is the Spallation Neutron Source (SNS) collaboration with the Argonne, Brookhaven, Lawrence Berkeley, and Los Alamos national laboratories and the Thomas Jefferson National Accelerator Facility (see Sect. 4.1.1). The SNS project has been cited by DOE as an outstanding example of interlaboratory collaboration.

Table 6.1
Major ORNL partnerships and collaborations

Activity and Partners	Description
Science	
Spallation Neutron Source Argonne, Brookhaven, Lawrence Berkeley, Los Alamos, Thomas Jefferson National Accelerator Facility; the neutron user community (universities and industry)	Design and construction of an accelerator-based facility (total cost: $1.4 billion) to provide the world's most intense pulsed neutron beams. Each laboratory is responsible for a major component or system and its integration into the facility; this collaborative approach to designing and constructing a major research facility provides a model for future DOE projects.
Center of Excellence for the Synthesis and Processing of Advanced Materials Argonne, Brookhaven, Lawrence Berkeley, Idaho, Los Alamos; Ames	Coordinated, cooperative multilaboratory research partnerships on the synthesis and processing of advanced materials for energy technologies. ORNL is engaged in projects on Mechanically Reliable Surface Oxides for High Temperature Corrosion Resistance, Ultrahigh Temperature Intermetallics, Welding and Joining, Magnet Materials, Metals Forming, Microstructural Engineering with Polymers: In-situ Composites, and Advanced Photovoltaics.
Materials MicroCharacterization Collaboratory Argonne, Lawrence Berkeley; University of Illinois at Urbana-Champaign; National Institute of Standards and Technology; many industrial partners	Interactive virtual laboratory to provide remote access to characterization tools used in materials research and interaction among researchers. Tasks include the definition, development, testing, and procurement of hardware and software for remote collaboration, focusing on microscopy and microanalysis.
Advanced Computational Testing and Simulation (ACTS) research Argonne, Lawrence Berkeley, Lawrence Livermore, Los Alamos, Sandia; University of Southern California	Facilitation of future collaboration across the DOE complex. Participants develop mechanisms, interfaces, and modules that enable flexible interoperability of tool kits, codes, and advanced computing resources for mission-critical DOE problems.
Atmospheric Radiation Measurement (ARM) Program Argonne, Brookhaven, Lawrence Berkeley, Lawrence Livermore, Los Alamos, Pacific Northwest, Sandia; National Renewable Energy Laboratory; other government agencies, industry, universities, and international organizations	Data collection and analysis to enhance the understanding of global and regional climate change. This effort includes the development of methods of data management and information exchange to facilitate future interlaboratory integration.
National Center for Research on Enhancing Carbon Sequestration in Terrestrial Ecosystems (CSiTE) Argonne, Pacific Northwest; universities; other research institutions	Distributed research center for studies of carbon sequestration in vegetation and soils. Researchers study ways to increase carbon storage, extend its duration, and verify and measure the amount of carbon stored.
Joint Genome Institute Lawrence Berkeley, Lawrence Livermore, Los Alamos; Stanford Human Genome Center	DOE-sponsored collaboration in functional genomics and bioinformatics.
Fusion Energy Sciences Argonne, Pacific Northwest, Sandia; Princeton Plasma Physics Laboratory; universities; General Atomics and other industry partners; international partners	Broadly collaborative programs to establish the science base for development of fusion as an energy source. This effort spans collaborations on experiment design and operation (National Spherical Torus Experiment, National Compact Stellarator Experiment, Quasi-Poloidal Stellarator), technology development and remote collaborations (Virtual Laboratory for Technology), and high-performance computing.

Table 6.1 (continued)
Major ORNL partnerships and collaborations

Activity and Partners	Description
Science (continued)	
Southern Appalachian Man and the Biosphere Federal agencies; states of Georgia, North Carolina, and Tennessee; Appalachian Regional Commission; Southeast Natural Resource Leaders Group	Public/private partnership promoting environmental health, sustainable economic use, and cultural values across the Southern Appalachians, a component of the Man and the Biosphere (MAB) Program established by UNESCO.
Tennessee Mouse Genome Consortium University of Tennessee, Vanderbilt University, Meharry Medical College, St. Jude Children's Research Hospital, East Tennessee State University, University of Memphis	Acceleration of the development and analysis of mouse models for human diseases.
Energy Resources	
Bioenergy Feedstock Development Program National Renewable Energy Laboratory; U.S. Forest Service, U.S. Department of Agriculture, Tennessee Valley Authority; universities; research institutes; industry	Mission-oriented program of research and analysis with a goal of developing and demonstrating environmentally acceptable crops and cropping systems for producing large quantities of low-cost, high-quality biomass feedstocks
Superconductivity Partnership Initiative Argonne; Southwire Co. and other industry partners; electrical utilities	Development, fabrication, and use of high-temperature superconducting (HTSC) electric power systems; a power cable developed through this initiative has been deployed at a Southwire manufacturing facility.
Partnership for a New Generation of Vehicles Other DOE laboratories; other federal agencies, universities; DaimlerChrysler, Ford, General Motors, and other industries	Development of technology that can be used to create environmentally friendly vehicles with up to triple the fuel efficiency of today's vehicles and comparable affordability, performance, and safety.
Industries of the Future Other DOE laboratories and facilities; other federal agencies; universities; industry	Coordination of R&D for energy-intensive materials and process industries; includes development of road maps and creation of broad R&D partnerships.
Applied CarboChemicals CRADA Argonne, Pacific Northwest; National Renewable Energy Laboratory; Applied CarboChemicals	Development of cost-competitive chemical feedstocks from renewable resources.
National Transportation Research Center University of Tennessee; Development Corporation of Knox County	Partnership between the public and private sectors to develop new transportation systems that are affordable and that address the needs of the public in safety, security, and convenience. Specialized transportation research laboratory facilities provide tools for industry and other research partners.
GREENTIE International Energy Agency; member nations	Information network for distributing information on suppliers of technologies that reduce greenhouse gas emissions.
Public Power Institute Tennessee Valley Authority	Mutually beneficial collaborations to develop, demonstrate and deploy technologies for efficient and environmentally beneficial renewable energy production and use.

Table 6.1 (continued)
Major ORNL partnerships and collaborations

Activity and Partners	Description
Environmental Quality	
Consorcio Educativo para la Proteccion Ambientale Argonne, Sandia; two Mexican universities, three Chilean universities, U.S. universities serving Hispanic students; industry	Environmental partnership initiative that provides for joint research, student exchanges, faculty development, curriculum development, creation of bilingual educational materials, and other cooperative activities.
Environmental Management Science Program Other DOE laboratories; universities	Joint DOE-SC/DOE-EM program to reduce the cost and risk of cleanup through targeted basic science research. Projects address a range of environmental problems and draw on expertise from a variety of scientific disciplines.
Strategic Environmental Research and Development Program (SERDP) Pacific Northwest; other DOE laboratories; U.S. Department of Defense, Environmental Protection Agency, other federal agencies	Multiagency program funded through the U.S. Department of Defense to identify, develop, demonstrate, and transition environmental technologies that relate directly to defense mission accomplishment.
National Nuclear Security	
Interlaboratory Task Force for Unexploded Ordnance 14 DOE laboratories and facilities	Support for U.S. Department of Defense and other national and international entities concerned with the detection and disposition of land mines and other forms of unexploded ordnance
Nuclear Criticality Safety Program Argonne, Lawrence Livermore, Los Alamos; Idaho; universities	Development of an improved and integrated DOE capability to predict criticality in nuclear fission systems through new experiments, benchmarking against available U.S. and international data, refinement of Monte Carlo computer models, and processing of nuclear data into standard working forms.
International Nuclear Safety Program DOE laboratories and facilities; Russia and former Soviet Union nations; industry	Identification and development of commercial opportunities for scientists and engineers formerly involved in weapons programs (nuclear, chemical, and biological) of the former Soviet Union. In the Nuclear Cities Initiative, ORNL is paired with Sandia to serve the Russian city of Krasnoyarsk. The Initiatives for Proliferation Prevention program focuses on the Newly Independent States.
U.S./FSU Program of Cooperation on Nuclear Material Protection, Control, and Accounting DOE laboratories and facilities; Russia and former Soviet Union (FSU) nations; universities; industry	Reduction of the risk of nuclear weapons proliferation by strengthening security and developing Material Protection, Control, and Accounting (MPC&A) systems at sites containing weapons-usable nuclear materials.
U.S. Plutonium Disposition Activities DOE laboratories, facilities, and operations offices; industrial nuclear fuel cycle entities; nuclear power plant owner/operators; and nuclear safety regulators	Definition, development, and demonstration of technologies required for the disposition of surplus weapons-grade plutonium.
Joint U.S./Russian Plutonium Disposition Activities DOE laboratories and facilities, Russian research institutes, industrial nuclear fuel cycle entities, nuclear power plant owner/operators, and Russian nuclear safety regulators	Development, demonstration, and licensing of technologies and facilities required to implement plutonium disposition in reactors.

Other notable collaborative efforts include

- the PHENIX detector for the Relativistic Heavy Ion Collider at Brookhaven;
- the Genome Annotation Consortium, through which ORNL is working with Argonne, Lawrence Berkeley, Lawrence Livermore, Los Alamos, several universities, and other research institutions to provide a comprehensive sequence-based view of genomes; and
- the Probe test bed for comparative evaluations of storage-intensive applications, which links computational resources at ORNL and the National Energy Research Supercomputing Center.

The four national laboratories managed and operated by Battelle—ORNL, Brookhaven National Laboratory, the National Renewable Energy Laboratory, and Pacific Northwest National Laboratory—are working together to increase the value of science and technology delivered to DOE and related agencies by optimizing the performance of the "system" of these four laboratories. Key activities include joint strategic planning, the production and maintenance of an inventory of the assets of this four-laboratory system, program integration as appropriate to capitalize on the diverse strengths of the laboratories, development of work for other federal agencies and other customers, and building relationships with other DOE contractors. This effort is promoted by regular meetings of the chief research officers of the four laboratories and by ORNL participation in technical networks that link researchers at the four laboratories by area of expertise.

6.2 • University Partnerships

Our University Partnerships Initiative is aimed at increasing the value of science and technology at ORNL through active involvement of faculty and students in Laboratory programs. The initiative also supports DOE's commitment to helping to educate the next generation of scientists, engineers, technicians, and educators.

The University Partnerships Initiative builds on ORNL's current involvement in research partnerships with universities, many of which also have a significant education component (see Sect. 8.2). It includes the following elements:

- expanding collaborative programs with UT in areas of mutual interest;
- continuing the joint hiring of scientists and engineers with the six UT-Battelle core universities and expanding this program to include a wider set of universities;
- working with ORAU to facilitate research partnerships with its member institutions;
- developing and expanding research partnerships with Tennessee colleges and universities, historically black colleges and universities (HBCUs) and other minority educational institutions (MEIs), and prominent universities across the country; and
- developing the Oak Ridge Center for Advanced Studies to encourage interactions between ORNL researchers and university faculty and students.

The initiative is expected to support recruitment at the Laboratory, provide additional opportunities for graduate students to conduct research at ORNL, and offer outlets for ORNL staff members for sabbaticals and research appointments.

With roots in the Laboratory's early history, the long-standing partnership between ORNL and UT spans a broad spectrum of R&D and other activities, as indicated in Table 6.2. 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 in biological sciences, computational sciences, energy and environment, heavy ion research, and neutron sciences represent additional tools for combining the resources of these institutions for research and education. As described in Sect. 7.3, the state of Tennessee has pledged funding to construct new facilities at ORNL to house three of these institutes. The Joint Institute for Heavy Ion Research is already located in a UT-owned facility at ORNL, and the Joint Institute for Energy and Environment is expected to remain at UT's Knoxville campus.

Table 6.2
Interactions between ORNL and UT Knoxville

Joint Institutes:
Joint Institute for Biological Sciences
Joint Institute for Computational Sciences
Joint Institute for Energy and Environment, with the Tennessee Valley Authority
Joint Institute for Heavy Ion Research, with Vanderbilt University
Joint Institute for Neutron Sciences
Science Alliance, a Tennessee Accomplished Center of Excellence:
Distinguished Scientist Program
Joint Faculty Program
University Graduate Programs that draw on ORNL resources:
Graduate School of Genome Science and Technology (based at ORNL)
Graduate Program in Ecology and Evolutionary Biology
Joint Program in Mixed-Signal VLSI and Monolithic Sensors
Academy for Teachers of Science and Mathematics
Advanced Thermal Analysis System Laboratory
Center for Environmental Biotechnology
Composite Materials Science and Processing Laboratory
Measurement and Control Engineering Center
National Transportation Research Center
Netlib, a collection of mathematical software, papers, and databases
Nuclear Structure Theory Program
Project SEE (Satellite Energy Exchange), with NASA Marshall Space Flight Center, the University of Virginia, and the Russian Space Institute
UT-ORNL Graduate Fellowship in Theoretical Quark-Gluon Plasmas
UT-ORNL Select Graduate Fellowship for the Outstanding Applicant in Condensed Matter Physics

Two collaborative activities link ORNL and UT resources with those of other partners to address public and private sector needs in areas of growing importance, both regionally and nationally: transportation and human health.

The National Transportation Research Center (see Sect. 5.2.1) provides resources for the development of new transportation systems, including specialized transportation research laboratory facilities that are available to industry and other research partners. These resources are now housed in a modern facility, located in west Knox County, that is readily accessible to the center's partners and customers.

The Tennessee Mouse Genomics Consortium links ORNL, UT, East Tennessee State University, the University of Memphis, Vanderbilt University Medical Center, St. Jude Children's Research Hospital, and Meharry Medical College (an HBCU) for collaborative research in developing mouse models for human diseases. This arrangement is the result of an initiative undertaken through the Joint Institute for Biological Sciences (see Sect. 4.2.6).

ORNL is also an active partner in six of the nine centers of excellence established at UT in 2001.

- The Advanced Materials Laboratory, led by an ORNL-UT Distinguished Scientist, will create new materials using computer-intensive modeling and experiments. UT and ORNL scientists in materials science and engineering, chemistry, chemical engineering, and physics will collaborate.
- At the Center for Environmental Biotechnology, UT and ORNL scientists will combine electronics and bioengineered organisms to develop technologies that offer real-time, on-site monitoring of hazardous materials, with an emphasis on moving research results into commercial applications.

- At the UT Food Safety Center of Excellence, UT and ORNL specialists in biochemistry, reproductive biology, food-service management, parasitology, infectious diseases, and risk assessment are establishing research programs to investigate critical points in animal and plant production with the aim of controlling the spread of food-borne pathogens.
- The Genomics and Bioinformatics Center of Excellence conducts research on how genes function (focusing on DNA sequencing, analysis of gene mutations, and the use of robotics and nanotechnology to study gene patterns), and bioinformatics, the organization and analysis of genetic data.
- The Information Technology Research Center builds on ORNL and UT capabilities in scientific and high-performance network computing to create new types of information technology, empower research through new technology, and study the effects of its use.
- The UT Center of Excellence for Structural Biology will expand the frontiers of knowledge in biomolecular structure and function, in partnership with ORNL's Center for Structural Molecular Biology (see Sect. 4.2.2).

A new educational activity promotes economic development in the region. ORNL and UT have partnered with the Tennessee Technology Development Corporation to launch the Technopreneurial Leadership Center, a graduate program that is designed to give students the opportunity to launch new technology companies. The program includes an agreement for access to and licensing of key ORNL technology patents to the student teams/companies that complete the Technopreneurial Leadership Center program.

The six UT-Battelle core universities have made major commitments of resources to various programs of collaboration with ORNL, including joint faculty, shared research programs, and development of new joint institutes. As part of the University Partnerships Initiative, UT-Battelle plans to establish additional relationships with major research universities to generate more joint appointments, collaborative research, graduate student opportunities, and regional support for ORNL.

The Laboratory will continue its interactions with Tennessee's Centers of Excellence program for public higher education, which supports 26 Centers of Excellence and a number of Chairs of Excellence at Tennessee Board of Regents (TBR) institutions. ORNL is also a member of a coalition that unites several TBR schools, the Tennessee Biotechnology Association, TennesSeed, and Cumberland Emerging Technologies in a project designed to connect the knowledge at Tennessee universities and laboratories with the development of new products and services. The coalition will use a grant from the National Science Foundation to promote and support innovation and economic development.

ORAU has formed an EPSCoR Council to develop partnerships between the Laboratory and universities from states participating in the Experimental Program to Stimulate Competitive Research (EPSCoR). ORAU has also led the formation of an HBCU/MEI Council to work with the Laboratory on the development of more R&D partnerships between ORNL and HBCUs and other MEIs.

At ORNL, an HBCU/MEI Senior Management Team, championed by the Deputy Director for Science and Technology, is leading an HBCU/MEI Outreach Initiative with three major components: a summer research program for HBCU/MEI faculty, internships for students from HBCUs and MEIs, and outreach to HBCUs and MEIs, including campus visits by ORNL staff and other interactions. The first summer faculty research appointment began in May 2001. ORNL has extended offers to seven faculty members from six HBCUs/MEIs. Through the National Urban League's Black Executives Exchange Program (BEEP), one ORNL researcher is teaching at an HBCU/MEI campus, and two more are scheduled to do so in the near future. The SNS project sponsors a summer intern program in Oak Ridge through the National Science Foundation's Alliance for Minority Participation (AMP).

Through its National Security Directorate, ORNL is linked to the Minority Educational Institutions Technology Partnerships Program (MEITP) administered by the Advanced Technologies organization at the Y-12 National Security Complex. The MEITP cultivates long-term, mutually beneficial relationships with MEIs that result in cooperative research, educational, and economic ventures.

ORNL and ORAU have established the Oak Ridge Center for Advanced Studies (ORCAS) to serve as a center of intellectual inquiry and a place of interaction between Laboratory staff and university faculty and students. The state of Tennessee has pledged $4 million for construction of a facility to house ORCAS, which will provide courses to advance the professional competencies of ORNL staff, on-site graduate courses taught by UT and core university faculty, and a "think tank" where ORNL and outside experts can carry out intensive studies of special topics in science and technology. Construction of this facility, which will also house the Joint Institute for Computational Sciences, is expected to begin in FY 2002.

ORNL is a collaborator on 6 of 13 university-led projects funded through DOE's Energy Efficiency Science Initiative. Academic outreach is also reflected in subcontracted R&D with university partners, which was estimated at $28 million in FY 2000. This included about 10 subcontracts with HBCUs and MEIs, representing funding of about $600,000.

6.3 • Industry Partnerships

As a DOE laboratory, ORNL establishes relationships with a variety of industry partners engaged in technology innovation and discovery. Approximately one-quarter of ORNL's research guests each year are from industry.

ORNL is an active partner in several industry consortia, including the Partnership for a New Generation of Vehicles (PNGV), which supports cooperative projects involving programs in DOE's Office of Science and Office of Energy Efficiency and Renewable Energy (DOE-EE) and in the National Nuclear Security Administration's Office of the Deputy Administrator for Defense Programs. ORNL also continues to pursue the implementation of partnerships with companies and consortia representing the industries participating in the DOE-EE Industries of the Future initiative. In January 2001, ORNL was named as a partner in four new cost-shared projects that support the aluminum industry and one that supports the steel industry.

Partnerships to transfer ORNL's knowledge and technology to the private sector support the creation of new businesses and strengthen the economy. The Laboratory's activities in technology transfer are described in Sect. 8.1.

7 • Operations and Infrastructure

The Oak Ridge National Laboratory (ORNL) is managed for the U.S. Department of Energy (DOE) by UT-Battelle, a partnership between the University of Tennessee (UT) and Battelle. The UT-Battelle Leadership Team comprises the Laboratory Director; the Deputy for Science and Technology and the Deputy for Operations; six Associate Laboratory Directors (ALDs) with line responsibility for ORNL's research and development (R&D) missions; and seven support directors, who are responsible for establishing the policy and tools and maintaining the subject matter expertise that enable the ALDs to execute their operational responsibilities in delivering on the Laboratory's mission assignments.

UT-Battelle is committed to simultaneous excellence in science and technology; laboratory operations and environment, safety, and health (ES&H); and community service. This commitment guides our approach to continuing the safe, secure, and cost-efficient operation of ORNL. The Laboratory Agenda (see Sect. 3.2) outlines how we will sustain and improve ORNL's ability to serve the needs of DOE and the nation through responsible stewardship of the resources entrusted to our care. Specific plans for delivering improvements in Laboratory operations and ES&H are discussed in this section.

7.1 • Environment, Safety, and Health

UT-Battelle is committed to protecting ORNL's workers, the public, and the environment. To this end, our philosophy is to embed ES&H practices in the work process, so that outstanding ES&H performance is achieved as an integral element of doing the work of the Laboratory. This will be accomplished by clearly assigning line accountability for ES&H; enabling line management and workers with effective, efficient processes and tools; and providing field-deployed ES&H subject matter experts to support the work. This approach incorporates our commitment to the core functions and guiding principles of integrated safety management (ISM).

7.1.1 • Goals and Objectives

Our primary goal is to establish efficient work processes and instill cultural behavior that produce outstanding ES&H performance as a natural part of doing work. We will achieve this goal by building on the successes of the past. Through our Enhanced Operational Discipline Initiative, we will enhance ORNL's overall operational performance by improving the discipline and integration of our operations. Key objectives are

- building on the Laboratory's ISM program to extend implementation to the benchtop, incorporating comprehensive work planning with tailored hazard controls;
- establishing aggressive self-assessment, on-line lessons learned, and robust management of corrective actions to drive continuous improvement at the work activity level; and
- emphasizing environmental protection in ISM to reduce environmental vulnerabilities, enhance waste minimization, and empower waste generators to assume responsibility for the materials that they use and the waste that they produce.

7.1.2 • Current Conditions

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

Established in 1943 as an element of the Manhattan Project's Clinton Engineer Works, ORNL has one of the oldest physical plants in the DOE laboratory system, with a substantial legacy of ES&H problems that need correction. Several hundred sites at ORNL are contaminated with radionuclides and hazardous chemicals. Contamination of surface water, groundwater, and biota has also been detected and reported. Remediation and waste management activities relating to these issues have been under way for several years. In 1998, responsibility for these activities was transferred to Bechtel Jacobs Company LLC as part of the management and integration (M&I) contract for DOE's environmental management (EM) programs in Oak Ridge.

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

ORNL also operates one reactor, the High Flux Isotope Reactor. Several other reactors have been permanently shut down and are awaiting deactivation and decommissioning. Several isotope production facilities have also been shut down because of changing missions, and removal of radioactive materials from these facilities is in progress. Current operating missions include the processing of such radio-isotopes as ^{252}Cf and ^{192}Ir and the storage of ^{233}U. More than 35 facilities at ORNL are used by Bechtel Jacobs 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.

ORNL's ISM system (ISMS) requires each line organization to have at least one ISMS plan to customize the ISMS principles and core functions to its operations. Organizations with complex or special-hazard situations have additional ISMS plans tailored to specific programs or facilities. Implementation of the Laboratory's ISMS was verified in September 2000. The ISMS will transition to a systems-based program next fiscal year consistent with the Standards-Based Management System (SBMS) currently under development at ORNL (Sect. 7.1.3).

7.1.3 • Plans

Through our Enhanced Operational Discipline Initiative (see Sect. 7.2.1), we are developing an integrated SBMS covering all aspects of Laboratory business. The SBMS translates laws, DOE orders, and regulatory requirements into Laboratory-wide subject area documents (procedures and guidelines) that are current, accurate, and relevant to the work being performed by staff. SBMS information is based on an evaluation of external requirements (i.e., directives and Federal, state, and local laws), corporate policies, and best management practices that have been determined to be applicable to ORNL operations and processes. While the SBMS does not deliver facility-, organization-, or program-specific operating procedures, guidance, and requirements, it does provide the ORNL baseline requirements to be maintained in the development, delivery, and control of such internal operating procedures and documents. The SBMS facilitates integration of the Laboratory's business and operating processes through an integrated set of management system descriptions. To date, 23 management system descriptions have been approved and approximately 35% of planned subject area documents have been issued (as of December 31, 2001).

As part of this effort, we are developing systems and tools that support the embedding of environment, safety, health, and quality (ESH&Q) practices and principles into the benchtop work planning and execution process, so that ESH&Q becomes a natural element of doing work. Field-deployed subject matter experts provide support to customers through a "purchased service" model. This system is expected to reduce costs, improve customer service, and enhance the Laboratory's ES&H performance.

An Operations Improvement Program (OIP) instituted in FY 2001 supports strategic investments in ORNL's work processes, such as the development and deployment of SBMS. Additional OIP projects that will be carried out during FY 2002 include the following:

- Enhancement of operations in nonreactor nuclear facilities. This includes configuration management, cross-training, and extending the facility management model discussed in Section 7.3.3.2 to nonreactor nuclear facilities.
- Continued operation of the Chemical Management Center, which provides a centralized collection of usable commercial chemical products and facilitates the redistribution of these products.
- Completion of a Facility Environmental Vulnerability Assessment (FEVA) begun in FY 2001.

Annual ES&H, quality, and infrastructure (ESHQ&I) budget formulation plans and submissions provide detailed documentation of plans for ensuring ES&H compliance.

Revitalization of the Laboratory's facilities to reduce the safety and health risks created by outdated infrastructure will be carried out through the Facilities Modernization Initiative described in Sect. 7.3.

7.1.4 • Environmental Management Activities

EM activities at ORNL are managed by Bechtel Jacobs. A Record of Decision (ROD) for cleanup of the Melton Valley Watershed was signed in September 2000. The ROD on future remedial actions in the Bethel Valley Watershed is being finalized. ORNL has participated as a stakeholder in these decision processes. Environmental restoration activities in the Bethel Valley Watershed, which includes the ORNL "main campus," could have a significant impact on Laboratory operations.

The Laboratory's ESH&Q Directorate will continue to work with Bechtel Jacobs and DOE's Oak Ridge Operations Office (DOE-ORO) to ensure effective remediation of legacy contamination. The Environmental Protection and Waste Services (EPWS) organization in the ESH&Q Directorate is responsible for a variety of regulatory programs to ensure ORNL compliance.

The decommissioning of expensive and aging infrastructure (see Sect. 7.3.5.2) is critical to our Facilities Modernization Initiative. It is essential to ORNL's future that the EM mission at ORNL continue to receive priority support and attention.

7.1.5 • Waste Management Activities

Waste management activities at ORNL are managed by Bechtel Jacobs. EPWS provides waste management support services to ORNL researchers to assure that fully characterized and certified waste is delivered to Bechtel Jacobs and its contractors while properly balancing cost and risk.

The Bechtel Jacobs approach to M&I implementation focuses on low-cost, fixed-price contracting of EM work scope to qualified vendors. This approach brings with it a number of issues that could have significant effects on ORNL, such as vendors' ability to operate the complex ORNL waste management infrastructure in a safe and compliant manner, respond to our waste generators, and be flexible enough to accommodate the changing waste needs of a multiprogram laboratory.

Responsibility for management of newly generated solid waste may be transferred from DOE's Office of Environmental Management to the Office of Science (DOE-SC) in the FY 2003 time frame. ORNL is planning for execution of the responsibilities associated with this transfer.

7.2 • Management Practices

7.2.1 • Performance-Based Management

The management and operation (M&O) contract between DOE and UT-Battelle provides for the use of performance measurement to promote continuous improvement and provides a basis for evaluating contractor performance. ORNL and DOE-ORO work together to develop an annual Performance Evaluation Plan, which links the strategic objectives and critical outcomes of the Laboratory Agenda with DOE's performance expectations through a set of performance goals, measures, and indicators. The Performance Evaluation Plan is incorporated into the M&O contract.

ORNL is committed to self-assessment of all business activities as a mechanism for evaluating the overall effectiveness of Laboratory organizations and promoting continuous improvement. In addition, DOE-ORO views the Laboratory's self-assessment program as a primary tool for performance measurement. As required by the FY 2001 Performance Evaluation Plan, a Laboratory-level self-assessment plan was delivered to DOE's ORNL Site Office and DOE-SC during the first quarter of FY 2001. Regular updates on performance and a formal status briefing at midyear were provided, and a formal self-evaluation report was delivered to the ORNL Site Office at year's end. Self-assessment plans are also maintained at the division and directorate level, and year-end self-evaluation reports from divisions and directorates were used in compiling the Laboratory-level report, as were the results of external assessments, internal audit reports, independent oversight, and customer survey data.

ORNL is implementing a Performance-Based Management System (PBMS) to expand the existing self-assessment program beyond ESH&Q compliance to an integrated system that provides for the assessment of all aspects of ORNL business. The PBMS will provide a means to

- interface with customers and stakeholders to determine the direction of the Laboratory through the development of performance objectives and indicators,
- develop methods to monitor performance against those objectives and indicators through creation of assessment plans,
- compare performance with expectations using tools defined in the various elements of the PBMS, and
- implement improvements identified through the performance assessment process.

The PBMS is a key element of the integrated set of management systems collectively known as the Standards-Based Management System (SBMS), which is being developed and deployed as part of our Enhanced Operational Discipline Initiative. The end result will be an integrated system for monitoring, assessment, and improvement of the Laboratory's performance.

7.2.2 • Human Resources

ORNL's Human Resources and Diversity Programs (HR&DP) Directorate provides consultation, advice, and support to line organizations in several areas of human resources, including recruitment and staffing, compensation and performance management, personnel and labor relations, benefit management, employee and organizational development, human resource information systems, work force diversity, quality of work life, and ad hoc consulting services. The Directorate is committed to delivering value-added, customer-focused, and cost-effective services to all Laboratory organizations. Its goal is to develop and maintain systems, programs, and policies that best enable ORNL to achieve its vision of simultaneous excellence in science and technology; laboratory operations and ES&H; and community service.

The Directorate continually reviews and evaluates its programs and approaches to ensure that efforts are appropriately aligned with and achieving results consistent with current initiatives, near-term critical outcomes, and longer range strategic objectives. A number of activities have been or are being undertaken to establish ORNL as an employer of choice in the research community and the region, in support of the Laboratory Agenda. Special emphasis is placed on enhancing the ability to attract and retain employees with strategic skills, enhancing the diversity of the work force, and identifying and implementing progressive work-life programs.

Within the HR&DP Directorate, the Staffing Management and Diversity Programs Division is charged with ensuring a coordinated effort to provide the Laboratory with a diverse pool of candidates for employment, thus supporting ORNL in addressing strategic skills needs and increasing the presence of minorities and women in senior management and senior individual contributor and researcher roles, a key UT-Battelle commitment.

A human resources information system (HRIS) developed as part of ORNL's SAP R/3 enterprise information system is now the primary platform for processing employee transactions and maintaining records. HRIS will also serve as a management information platform to give line organizations ready

access to employee demographic and labor cost information, supporting management decisions. Near-term efforts will be focused on transferring historical data and ancillary processing activities into SAP.

Human resources challenges for the planning period include the increasingly competitive market for workers with strategic skills. Significant numbers of employees are eligible to retire in the next several years, taking with them vast amounts of technical knowledge and corporate memory. These challenges will be met through a comprehensive staffing management approach that includes

- identifying strategic skills and knowledge requirements, evaluating turnover patterns to identify vulnerabilities, providing approaches to ensure a transfer of knowledge from our experienced contributors to those who will take on the challenges of the future, ensuring the implementation of competitive strategies to retain, attract, and reward those with strategic skills (see Sect. 7.2.2.1);
- providing an effective performance management component (see Sect. 7.2.2.2); and
- addressing employee "quality of work life" issues (see Sect. 7.2.2.3).

ORNL will continue working to recruit, retain, and develop a diverse work force; to promote understanding and valuing of differences; to create an environment that accommodates the future work force; and to ensure that the required skill sets and employee resources are available to support the Laboratory's business and research objectives.

7.2.2.1 • Securing and Maintaining Strategic Skills

The Staffing Management and Diversity Programs Division, with the active support of the line organizations, has developed an approach to ensuring the availability of strategic skills. Each functional organization has identified skill requirements and developed strategies to secure the required skills. The process ensures a review of internal skill resources as well as those potentially available at other Battelle-affiliated laboratories.

The Laboratory undertook a comprehensive needs assessment to provide a contemporary view of needs in employee and organizational development. Analysis of the results was completed in June 2001, and an implementation plan has been drafted. The plan identifies tasks to be undertaken during the next three years to meet top-priority training needs, improve succession planning and individual development planning, and support a mentoring/coaching process for high-potential employees.

7.2.2.2 • Performance Management and Compensation

ORNL has implemented a new performance management and compensation system. The need for changes in ORNL's compensation system was recognized and reported in the late 1990s. The new system responds to this need and is designed to support the Laboratory Agenda and DOE's missions by enhancing ORNL's ability to successfully attract, retain, and motivate staff.

The new system is a broadband hybrid that better responds to the contemporary needs of the Laboratory. The system provides appropriate controls while allowing for flexibility in responding to market pressures. In addition, this more contemporary system better accommodates staff development issues and can be readily adapted in response to organizational changes.

Continuing attention to the competitiveness of ORNL's salaries will be required during the planning period. A three-year program, to be completed in FY 2002, has brought ORNL's R&D salaries in line with the competitive market. This effort has also been extended on a targeted basis to address the competitiveness of some non-R&D salaries. We must continue to evaluate our pay programs and implement approaches that ensure the competitiveness of our salaries and at the same time support our commitment to drive down costs.

7.2.2.3 • Quality of Work Life

The HR&DP Directorate regards ORNL employees as its customers and places a premium on understanding their needs. Attention to employee issues and concerns is reflected in the development and implementation of programs and processes that support efforts to make ORNL an "employer of choice," thus ensuring that we maintain a highly motivated and productive work force.

Employee Benefit Programs

In April 2000, ORNL entered into a formal agreement under which Lockheed Martin Energy Systems, Inc., then the M&O contractor for the Oak Ridge Y-12 Plant, essentially served as a third-party administrator for ORNL health benefits and welfare and retirement savings plans. This approach best ensured a smooth and uninterrupted transition of benefits under UT-Battelle and provided an opportunity to review ORNL's benefit plan requirements and develop benefit plans that provide the most efficient and cost-effective delivery of benefits to employees.

The third-party administrator responsibility passed to BWXT Y-12 in November 2000 with the transition of the M&O contract for Y-12 (now known as the Y-12 National Security Complex). The Laboratory is fully and equally represented on the benefit administration and investment committees to ensure that ORNL's interests and assets are given appropriate consideration.

A comprehensive review of the benefit program in FY 2001 included a review of benefit plan designs, program administration, and communication strategies to ensure that our benefit strategies are aligned with the Laboratory Agenda. We will continue to review the benefit program on an ongoing basis to ensure that it is achieving desired results.

Work Force Diversity

The Laboratory is committed to achieving its strategic business objectives by capitalizing on the diversity of its work force. The Office of Federal Contract Compliance Programs (OFCCP) conducted a compliance review of ORNL in FY 2001 and took note of ORNL's model policies and procedures designed to prevent sexual and racial harassment in the workplace. In recognition of these efforts, ORNL has been placed on the OFCCP Region IV Racial/Sexual Harassment Honor Roll. ORNL has also received a DOE Award for Progress in Equal Employment Opportunity/Diversity.

In addition to its annual Affirmative Action Plan, which assesses progress toward meeting annual objectives, ORNL has established a Diversity Plan (updated in December 2000) that outlines a means for promoting a high-performance, diverse, and inclusive organization. This approach ensures development of clear objectives, establishes roles and accountability, and provides for a critical assessment of results.

All Laboratory divisions have Work Force Diversity (WFD) representatives appointed by division managers and directors to assist them in developing, implementing, monitoring, and reporting affirmative action. Each year, ORNL celebrates Martin Luther King, Jr., in January, Black History Month in February, Women's History Month in March, Asian Pacific American Heritage Month in May, Hispanic Heritage Month in September and October, Disabilities Awareness Month in October, and Veterans' Day and Native American Heritage Month in November.

Employee Concerns

ORNL's Employee Concerns Program provides a means for management to learn about and understand employee concerns. The program also serves to ensure that all employees know that their concerns and suggestions will be taken seriously and feel free to voice them. Key aspects of the program include an easy process for submitting suggestions and concerns, a specified time frame in which the employee's concern should be addressed, a two-step appeal process, and an alternative dispute resolution process.

Quality of Work Life/Work Environment Surveys and Actions

An initial "quality of work life" survey, to which 66% of salaried employees responded, provided information on a number of high-priority issues. We have taken action to address many of the top items that were identified. Efforts include the development of an on-site fitness center, financial planning programs, and improvements in physical facilities. A follow-on "quality of work environment" survey, with a 60% response rate, provided further information about employee perceptions of work organization, working conditions, supervision, communication, job satisfaction, and other topics.

7.2.3 • Security, Intelligence, and Nonproliferation

ORNL is committed to protecting cutting-edge research, national security interests, proprietary information, personnel, property, and the general public. The Laboratory fully supports DOE's efforts to strengthen counterintelligence and security at its facilities. Safeguards and security measures are focused on producing an overall security posture that is appropriate to ORNL's research missions and activities.

A graded approach that incorporates threat analyses, risk assessments, and cost/benefit analyses is applied to ensure appropriate protection of all security and safeguards interests, including classified and unclassified material and information, special nuclear material (SNM), and other U.S. government property. Threats to these assets and interests include compromise, loss, theft, diversion, espionage, sabotage, subversion, and other malevolent or inadvertent acts that may cause unacceptable risks to national security, economic advantage, worker or public health and safety, or the environment.

ORNL has a Site Safeguards and Security Plan (SSSP) and specialized security plans to address both routine operations and contingencies. Programs are in place to ensure physical security, property protection, nuclear material control and accountability, personnel security, information security, and computer and network security. Strategies developed and implemented to ensure the protection of site security interests are designed to assure the required levels of protection, while accommodating the multipurpose R&D missions of the Laboratory. Programs are also developed as needed to assess the potential for radiological or toxicological sabotage and mitigate the potential consequences of such events.

Under a prime contract with DOE-ORO, Wackenhut Services, Inc.–Oak Ridge (WSI-OR) provides selected protective security services for the Laboratory. Overall programmatic responsibility for management of most major security programs remains with ORNL, with the notable exception of the protective force situated at the Laboratory. The purpose of the WSI-OR prime contract with DOE-ORO is to provide the appropriate numbers of qualified personnel to support selected protective services activities at ORNL.

ORNL works in concert with WSI-OR to ensure proper protection of DOE interests at the Laboratory. The ORNL Security Department, part of the Laboratory Protection Division of ORNL's Facilities and Operations Directorate, also partners with ORNL line organizations, customers, and DOE to develop and maintain appropriate, cost-effective security systems and procedures for addressing protection issues.

A June 2000 safeguards and security inspection of ORNL conducted by DOE's Office of Independent Oversight and Performance Assurance led to several findings. Most of these concerned the protection of information. We have completed all of the corrective actions and opportunities identified in the inspection report.

Although relatively little work that must be shielded or protected for reasons of national security is conducted at ORNL, the events of September 11, 2001, changed the Laboratory's security environment. Recommendations from the "open campus" reconfiguration study completed in FY 2001 are being implemented as appropriate given the need for enhanced security. We have moved ahead with the transition to a building-based security perimeter, but we are also working with DOE and WSI-OR to control access to the Laboratory by establishing checkpoints at the east and west ends of Bethel Valley Road. This is viewed as a necessary and prudent step in protecting ORNL employees and assets.

During the planning period, we will continue working to ensure that safeguards and security measures are focused where appropriate and to configure the security perimeter of the site so that required levels of protection are provided to security interests with the minimum hindrance to the flow of people, equipment, and material throughout the site.

7.2.3.1 • Intelligence and Counterintelligence

Measures are in place to deter and neutralize foreign industrial or intelligence activities directed at or involving DOE programs, facilities, technology, personnel, and classified and unclassified information at ORNL. The ORNL-based Office of Counterintelligence provides support to the DOE Oak Ridge complex. The office tracks probes for classified, sensitive, or proprietary information by unauthorized

personnel; personnel seeking unauthorized access; and compromising behavior on the part of site personnel. This office also handles briefing and debriefing of ORNL staff who are traveling to other nations, with an emphasis on travel to sensitive countries, and provides training to ORNL hosts for foreign national visits and guest assignments to the site to ensure that hosts are fully cognizant of their responsibilities with respect to these visitors and temporary assignees to the Laboratory.

7.2.3.2 • Integrated Safeguards and Security Management (ISSM) Program

The Laboratory is in the process of instituting an Integrated Safeguards and Security Management (ISSM) program designed to improve the efficiency and security of the work being conducted at ORNL. The ORNL ISSM program will include all levels of activity and will require the direct involvement of all ORNL staff. Line management will be held both responsible and accountable for ensuring that security issues are addressed in all operations and research activities. Safeguards and security subject matter experts will work in conjunction with line managers and researchers to ensure that work at ORNL is performed securely and that the ISSM program is implemented successfully. An ISSM program coordinator/steward has been appointed, an ISSM program description has been included in the ORNL Standards-Based Management System (SBMS), and an ISSM implementation plan is in the execution phase. Implementation plans for ISSM during FY 2002 include the establishment of an ORNL ISSM Senior Management Council, to be chaired by a senior management ISSM champion; establishment of an ISSM working group chaired by the program coordinator/steward; development of an ISSM web site; deployment of a formal ISSM awareness program; and training of ORNL staff in ISSM program objectives, guiding principles, and core functions. Full ISSM program implementation at ORNL is planned for completion by the end of FY 2002.

7.2.3.3 • Physical Security

Protective force operations at ORNL are provided by WSI-OR under a prime contract with DOE-ORO. Operations for ORNL are designed to keep the facility, its employees and visitors, and all government property safe and secure while maintaining a "user-friendly" atmosphere with minimal impact to operations. The physical security team in the ORNL Security Department provides an integrated, site-specific safeguards and security program that includes programs for protecting critical infrastructure, SNM, and other government assets, including classified matter, controlled substances, precious metals, and other sensitive items.

Protection of DOE property and unclassified facilities is provided by policies, strategies, and physical protection measures detailed in the *Property Protection Policy Guide for the Oak Ridge National Laboratory* (ORNL-LS-G3, December 1998). The protection of SNM and classified matter security interests is addressed in both the Site Safeguards and Security Plan and a Site Security Plan. Elements such as access controls, protective forces, barriers, and the Property Management System are integrated in a graded program that provides appropriate levels of protection for facilities and property. The Laboratory Protection Division assists organizations in developing protection elements tailored to fit the needs of their operations while providing protection in accordance with DOE and ORNL requirements and guidance.

As described in Sect. 5.4.1, Building 3019 at ORNL provides shielded, safeguarded storage of ^{233}U. Defense Nuclear Facility Safety Board Recommendation 97-1, "Uranium-233 Storage Safety at Department of Energy Facilities," is being implemented through the ^{233}U Inspection and Repackaging Project (IRP), which provides for the inventory, inspection, and repackaging (as needed) of materials stored in Building 3019. Additional protective force staffing will be required during the project to ensure that security requirements are met.

The ORNL Security Department, WSI-OR representatives, and the ORNL Chemical Technology Division have developed contingency security planning for the phased implementation of this project. During the early stages of the IRP, Category III quantities of SNM stored in Building 3019 will be accessed, and some additional security measures will be applied with available resources. Later, Category I quantities of SNM will be accessed, and additional protective force staffing will be required. The

National Nuclear Security Administration's Deputy Administrator for Defense Programs (DOE-DP) will fund the costs associated with both additive security requirements and operational issues involving the ^{233}U IRP.

The transition to a building-based security perimeter, using technology (e.g., electronic card readers) to control access, as appropriate, is under way. This action should reduce the cost of physical security, improve access for guests and visitors, enhance the protection of information, and simplify and strengthen processes supporting foreign national visits and assignments. The new state-funded and privately owned buildings scheduled for construction as part of the ORNL Facilities Revitalization Program (Sect. 7.3.3.1) will incorporate these security features. Specifically, these new facilities will include automated access controls (using proximity card reader technology) at building perimeters, a key-and-lock program designed to provide appropriate levels of protection for different areas of the buildings, and intrusion detection system equipment and closed-circuit television (CCTV) coverage for sensitive areas such as communications rooms and classified work areas. The Laboratory Protection Division has also established a procedure within the SBMS that requires safeguards and secuity subject matter experts in the ORNL Security Department to work with facility managers for all ORNL buildings to develop formal, written Facility Protection Agreements. These agreements will establish the security operation practices for each facility.

7.2.3.4 • Information Security

Protection and control of classified and sensitive information includes the following elements:

- Operations security (OPSEC)
- Classified matter protection and control (CMPC)
- Technical surveillance countermeasures (TSCM)
- Classification and information control

All of these elements are addressed in Laboratory directives.

The Security Department manages the CMPC and TSCM functions to ensure appropriate levels of protection against unauthorized access, loss, or compromise of classified matter under the purview of the Laboratory. The physical protection of information includes an integrated system of information security activities, programs, systems, and policies to assure the protection of sensitive technological and proprietary data as well as classified information. This system includes the ORNL OPSEC program.

Identification and handling of classified and other sensitive information is overseen by the ORNL Office of Technical Information and Classification, which provides guidance and consulting in this area to Laboratory staff. The ORNL Technology Transfer and Economic Development Directorate and the General Patent Counsel within the ORNL Legal Directorate also contribute to ensuring the protection and effective management of the Laboratory's intellectual property.

7.2.3.5 • Cyber Security

The Computer and Network Security (CNS) group in ORNL's Networking and Computing Technologies Division is responsible for both unclassified and classified cyber security programs at ORNL. This group provides a dedicated ORNL resource for responding to the challenges of cyber security, drawing on a long history of effective and aggressive cyber security at ORNL. The Laboratory's technical expertise is a key resource in staying ahead of the technical challenges in this area.

The CNS mission is to protect information on ORNL automated information systems (AIS), commensurate with the risk of loss and harm, and to protect access to and from AIS on the Oak Ridge Network. CNS staff work with personnel in the Networking and Computing Technologies Division, with the Integrated Operations Support Division, and with the designated division computer security officers (DCSOs) within each ORNL division to ensure effective implementation of the Laboratory's computer security program.

To optimize cyber security, ORNL must balance the need to protect resources and information from unintended use or modification and the requirement for openness of resources and information for authorized public and collaborator access.

An integrated security feature on ORNL's internal Web server, "Doorkeeper," reduces the risk of unauthorized access to access-controlled pages. Intrusion attempts are reported to DOE's Computer Incident Advisory Capability (CIAC), with "cease and desist" messages sent to offenders. Users of the central electronic mail system are aggressively protected from viruses at the server level. This saves computer users a great deal of effort compared to the experience at other institutions.

Remote access to the Laboratory's user facilities is an essential element in the "virtual laboratory" concept. This access supports ORNL's science mission and is essential to the ability to work with subcontractors and other partners over the Internet. An enterprise-scale Virtual Private Network (VPN) capability allows partners and collaborators to use their existing Internet connections to access the Laboratory's resources securely over the Internet. Other cyber-related technological enhancements will be installed; these include a network perimeter (firewall), other secure remote access tools, and internal information segregation.

Employees and subcontractors who send or personally carry computer hardware and software outside the United States must follow requirements in accordance with U.S. export control laws and regulations. The Contracts Division within the ORNL Business and Information Services Directorate provides guidance and assistance in export compliance.

7.2.3.6 • Foreign National Visits and Assignments

The ORNL Security Department manages the Laboratory's Foreign National Visits and Assignments (FNV&A) Program. The program, which is conducted in accordance with DOE Notice 142.1, "Unclassified Foreign National Visits and Assignments Program," July 14, 1999, DOE Notice 205.2, "Foreign National Access to DOE Cyber Systems," November 1, 1999, is applicable whenever a "presence" at the Laboratory is requested for a foreign national.

All requests for foreign national visits or guest assignments to the Laboratory are processed by the Laboratory Protection Division. Integrated within the formal approval process are a requirement for visit and/or assignment hosts to receive recurring training from the Office of Counterintelligence (see Sect. 7.2.3.1), a requirement for hosts to formally acknowledge personal acceptance of responsibility for adherence to an applicable security plan for the visit or assignment, and, when necessary (e.g., for visitors or assignees from sensitive countries), documentation of assurance that a required Indices Check has been completed. Only when all requisite actions have been completed is visit or assignment approval referred to the Laboratory Director or authorized delegates for approval. Also, when questions or issues arise with respect to a particular visit or assignment, the Laboratory's Non-Citizen Access Review Committee is convened to evaluate issues and to make a final recommendation to the authorized approval authority on whether (1) the visit or assignment should be allowed to proceed, (2) supplementary security measures should be applied, or (3) the visit or assignment should be denied.

7.2.4 • Information Resource Management

ORNL is committed to managing and using its technical and administrative information as both an institutional and a multinational asset. The goal is to create an environment in which access to and use of information is a nonintrusive enabler of achieving the R&D missions of ORNL while protecting valuable assets.

The Networking and Computing Technologies Division and the Integrated Operations Support Division work together to provide the strategic framework for information resource management for the Laboratory. These organizations also work with the ORNL Security Department to ensure information security (see Sect. 7.2.3.4) and cyber security (see Sect. 7.2.3.5). Outsourcing has been used to augment services and to provide access to capabilities not available at ORNL.

ORNL uses its information management expertise and extensive investments in computing and networking technology to enable the conduct of R&D. The *Information Infrastructure Strategic Plan (Rev. 1)* identifies four major focus areas that require strategic planning to meet the needs of ORNL staff in the future:

- Mobility/universal access—telecommuting, remote research, etc.
- Collaborative environment—multiprogram and multidisciplinary projects
- Intelligent tools for leveraging knowledge—improved interfaces and intelligent agents
- Integration of ORNL information enterprise—information architecture for more efficient use of systems

Implementation teams develop roadmaps for achieving improved user experiences in all of these areas. Cost-benefit analyses will be performed to ensure that cost savings are a key driver in implementation.

Other priority activities include implementation of a managed hardware and software program and development of core software standards to strengthen management support for information as a corporate asset.

The growth and popularity of the Internet have allowed ORNL to share more information than ever before with a global audience. The ORNL public Web site provides a means for the public to submit information, make comments, and request information. Web servers are the principal distribution point for information products from ORNL's information centers and databases.

Web access to key electronic information sources maximizes the availability of information to ORNL staff. Enhanced access to such information has been effected by a consortium of libraries at DOE laboratories. The Laboratory's Research Libraries have added half a million dollars worth of electronic journals, at no additional cost to ORNL, effectively tripling the size of the electronic journal collection.

7.2.4.1 • Scientific and Technical Information

Scientific and technical information (STI) is a primary product of ORNL's R&D efforts. Unless specified otherwise by the sponsor, ORNL research activities culminate in STI that is shared with researchers and the general public worldwide. Many of these publications are forwarded to DOE's Office of Scientific and Technical Information (OSTI), where they are made available for downloading on the Information Bridge (http://www.doe.gov/bridge). ORNL is now using an electronic document clearance process that enables documents to go electronically from the author's desktop into DOE's Information Bridge. Since January 2001, all of ORNL's submissions to OSTI have been electronic. In addition, much of the Laboratory's STI is now available through internal and external Web sites.

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 covering various technical disciplines in support of DOE and other customers (e.g., the National Aeronautics and Space 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.

7.2.4.2 • Administrative Information

Most of ORNL's core business applications—including most aspects of payroll, benefits, and human resources—are handled by a single business software system, SAP R/3 (see Sect. 7.2.5). Studies continue to evaluate implementation of additional functions supported by the SAP software suite. Internal and external interfaces are also being evaluated for replacement or elimination.

ORNL and the M&O contractor for the Y-12 National Security Complex previously shared several business systems (software, hardware, and related data). More than 90 shared systems were separated before April 1, 2000, and ORNL is aggressively separating the remaining non-SAP systems, creating an independent systems environment for the first time. This will become the baseline for all future activities.

ORNL continues to improve employee access to information needed in the daily conduct of operations. Web technologies are applied to increase desktop access to information, with an emphasis on reducing costs and increasing end-user efficiency. Activities include

- encouraging use of the Web as the preferred interface for forms and business applications;
- supporting Windows, MacOS, and UNIX client platforms;
- upgrading operating systems and telecommunications; and
- initiating a Managed Hardware Program (implemented in July 2001).

The Web has become the interface of choice for the Laboratory's internal administrative information and business applications and is the preferred interface for all strategic business applications. Information is distributed to staff through the Web, and most business processes have Web interfaces for staff input. The Managed Hardware Program provides staff members with an efficient and cost-effective way to acquire or upgrade to desktop computing resources that are preconfigured with the Laboratory's standard tools.

7.2.5 • Business Management

ORNL is dedicated to continuously improving its management practices and operations, making it a more effective and efficient organization that is prepared to meet future operational challenges. The business management organization provides comprehensive financial expertise and support to all Level 1 managers. The UT-Battelle Leadership Team addresses decisions affecting the Laboratory to ensure that business decisions enhance and support the future direction of the Laboratory. Laboratory-level financial decisions are reviewed and approved by the Leadership Team prior to implementation.

Our Maximizing Research Effectiveness Initiative enlists all staff in a commitment to achieve indirect cost reductions that will deliver more R&D per dollar spent and provide more resources for discretionary investments in capability development and infrastructure revitalization. ORNL is committed to achieving a composite multiplier of 1.7 by the end of FY 2003. Business management processes (travel, payroll, procurement, etc.) will be evaluated for possible process improvements and cost efficiencies. ORNL will also implement an integrated planning and budgeting process that ensures a structured, disciplined process for the allocation of the Laboratory's discretionary resources.

ORNL continues to optimize the SAP R/3 enterprise information system. SAP R/3 is a fully integrated information system that eliminates the need to maintain and update multiple databases, thus reducing the costs required to maintain a number of nonintegrated business systems. SAP also supports all client platforms (Windows, Mac, UNIX) and provides an aggressive Web interface strategy.

ORNL is providing additional enhancements (e.g., custom reports) to the current SAP system in an effort to further meet the needs of end users. Basic cost and procurement data and the Internal Approval Level process have been added to the SAP Web application to improve employee access to information. Additional systems and processes (such as travel and the Payroll, Absence, and Labor System) are currently being evaluated and may be absorbed into SAP in the future.

A new Laboratory organizational structure was implemented on October 1, 2001. This reorganization was undertaken to better align ORNL's capabilities with anticipated business opportunities, to eliminate a layer of management, and to reduce the cost of doing business. The number of research divisions was reduced from 19 to 16, a new Computing and Computational Sciences Directorate was established, and the section head level of management was eliminated.

Other changes in ORNL's business operations include the establishment of a structured process for reviewing and approving all indirect budgets, particularly division organization burden, program office costs, and other service centers. An Indirect Budget Review Committee is being established to ensure that we maintain a far more uniform and consistent treatment of indirect costs across the Laboratory. These management changes will play a major contributing role in the planned reduction of indirect costs.

7.3 • Site and Facilities Management

ORNL is committed to good stewardship of its resources, both in management of existing facilities and in planning for future needs. In addition to management and maintenance of buildings and

facilities at the main Laboratory site, UT-Battelle is responsible for (1) site and facility planning for ORNL and (2) management and planning for most of the undeveloped land area of the ~14,000-ha (34,424-acre) Oak Ridge Reservation.

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

The UT-Battelle Leadership Team has undertaken the revitalization of the ORNL campus. The scope of the revitalization effort includes the construction of new research and administration/support facilities, the renovation of existing facilities, and the consolidation of ORNL's work at the main Laboratory site in order to build an integrated research campus for the 21st century. This Facilities Modernization Initiative is a key element of the Laboratory Agenda (see Sect. 3.2).

The *ORNL Land and Facilities Plan* (updated annually; the current version is available on the World Wide Web at http://www.ornl.gov/~dmsi/landUse/plan.htm) provides information on land and facilities use and planning for the Laboratory. *Comprehensive Integrated Planning Process for the Oak Ridge Operations Sites* (ORNL/M-6717, September 1999; http://www.ornl.gov/~dmsi/cip/cip.htm) is a planning reference that identifies primary issues regarding major changes in land and facility use for three DOE sites, including the Oak Ridge Reservation. ORNL developed a *Strategic Facilities Plan* (ORNL/TM-2000/238) to support DOE-SC in preparation of an Infrastructure Needs Assessment Report to address the issue of modernizing its laboratories. The *Oak Ridge National Laboratory Facilities Revitalization Project—Project Management Plan* (ORNL/TM-2000/174) provides further details on ORNL's plans.

7.3.1 • Laboratory Description

ORNL's main site encompasses approximately 450 ha (1,100 acres) in the Bethel and Melton valleys, approximately 16 km (10 miles) southwest of the center of the city of Oak Ridge, Tennessee, with additional facilities located on the adjacent Copper Ridge. ORNL also occupies space at the Y-12 National Security Complex (formerly the Oak Ridge Y-12 Plant) and leases some space off site.

The ORNL site has many functions and requirements similar to those of a small city. It is supported by a dedicated fire department, a medical center, a security force, and a steam plant. Amenities include 290 km (180 miles) of roads, 55 km (34 miles) of overhead power lines, 8,230 m (27,000 ft) of steam lines, 30,480 m (100,000 ft) of treated water piping, and ~90 ha (225 acres) of mowed grounds.

As indicated in Table 7.1, buildings at the Melton Valley and Bethel Valley sites and Copper Ridge comprise ~316,000 square meters (3.4 million gross square feet) of building space; at Y-12, ORNL use accounts for ~88,000 square meters (0.95 million gross square feet) of building space.

Facilities accepted into DOE's EM program and those that are part of the waste management systems managed by Bechtel Jacobs under the M&I contract have been transferred to Bechtel Jacobs to facilitate the accomplishment of contractual responsibilities. With the exception of these facilities, ORNL has full responsibility for its Bethel Valley and Melton Valley sites and surrounding areas. ORNL is also responsible for management of an 8,530-ha (21,076-acre) portion of the ~14,000-ha (34,424-acre) Oak Ridge Reservation, including ORNL facilities and most of the ~8,000-ha (~20,000-acre) Oak Ridge National Environmental Research Park. At the Y-12 National Security Complex, ORNL has responsibility for building maintenance and ESH&Q functions as approved by Memoranda of Understanding with Y-12. ORNL has identified 129 facilities as surplus to its needs. Of these facilities, 89 are not contaminated and do not appear to meet criteria for transfer to the EM program.

Table 7.1
ORNL space distribution

Location	Buildings		Trailers		Total space, ft²
	Number	Space, ft²	Number	Space, ft²	
ORNL main site					
UT-Battelle (DOE-SC)	330	2,991,876	57	52,983	3,044,859
UT-Battelle (DOE-DP[a])	1	37,191	----	----	37,191
Bechtel Jacobs	130	445,482	32	26,662	472,144
Subtotal, ORNL main site	461	3,474,549	89	79,645	3,554,194
ORNL off-site: American Museum of Science and Energy	3	56,583	1	552	57,135
ORNL at Y-12	16	922,888	1	680	923,568
Leased off-site	5	297,064	—	—	297,064
Total	**485**	**4,751,084**	**91**	**80,877**	**4,831,961**

[a]The National Nuclear Security Administration's Deputy Administrator for Defense Programs owns Building 3019A.

ORNL actively uses the Condition Assessment Information System (CAIS) to document facility condition. A full-time condition assessment survey team performs assessments of ORNL facilities on a periodic basis, with each facility inspected at least once every three years. Replacement plant value (RPV) is presented in Table 7.2. The overall condition of the space is shown in Fig. 7.1, with details on use of space in Fig. 7.2 and a summary of building age in Fig. 7.3.

Table 7.2
Estimated replacement plant value
(in millions of FY 1997 dollars)

Facility type	Replacement cost
Buildings and structures	3,494
Utility systems	650
All other	300
Total	**4,444**

7.3.2 • Laboratory Site and Facility Trends

Trends in ORNL's site and facilities management and planning will reflect the aims of the Facilities Modernization Initiative: construction of new facilities, renovation and upgrading of existing facilities, disposition of excess facilities, and consolidation of operations at the main Laboratory site to establish an integrated research campus for the 21st century.

The Enhanced Operational Discipline Initiative will provide for more effective management of all Laboratory facilities. The space charge system will be used to promote more effective and efficient use of ORNL buildings and to provide a more equitable distribution of building maintenance costs.

The transfer of contaminated facilities to the EM program will continue to reduce the amount of square footage and the number of buildings for which UT-Battelle is responsible. In FY 2000, two filter

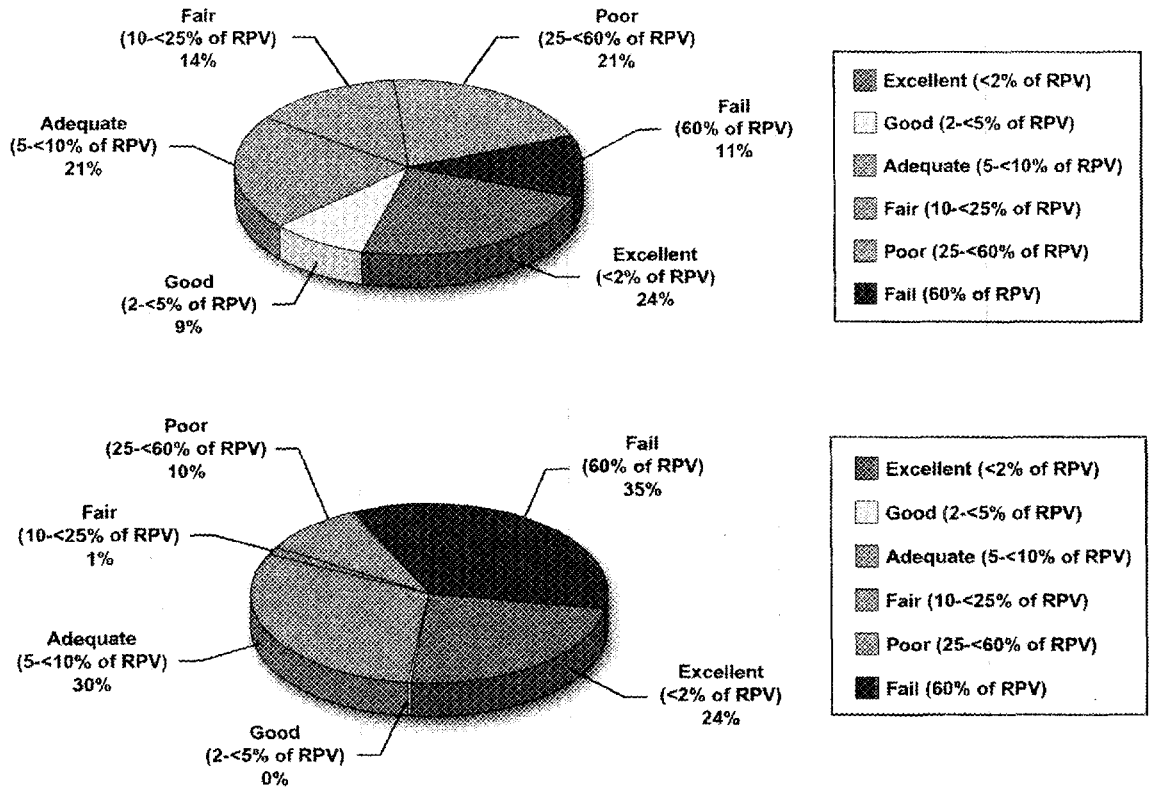

Figure 7.1
Condition of ORNL space at main ORNL site (top) and at Y-12 (bottom), based on cost of modification or repair as a percentage of replacement value. Adequate: cost < 10%. Minor rehabilitation: cost 10% to 25%. Major rehabilitation: cost >25% to 60%. Replacement: cost > 60%.

pits and a greenhouse associated with facilities previously transferred to the EM program were also transferred to the EM program. A contaminated laboratory facility at Y-12, Building 9735, and a "storage garden" at ORNL, Building 3597, will be transferred to the EM program in FY 2002.

As plans for consolidation of operations at ORNL proceed, the number of ORNL staff housed at the Y-12 National Security Complex will decline. A significant reduction in ORNL space at Y-12 was achieved in FY 2001 with the transfer of seven facilities (totaling approximately 220,000 square feet) to the National Nuclear Security Administration's Deputy Administrator for Defense Programs (DOE-DP).

Five facilities at Y-12 that were formerly occupied by ORNL staff, primarily in the Biology Complex, have been completely vacated. The remainder of the Biology Complex facilities, approximately 80,000 square feet, will be vacated by FY 2004 following construction of the new Laboratory for Comparative and Functional Genomics at ORNL (see Sect. 4.2.5).

During FY 2001, 18 noncontaminated facilities were added to the surplus facility list. New facilities added in FY 2001 include the Environmental and Life Sciences Laboratory and a 1,500,000-gal water tank on Chestnut Ridge.

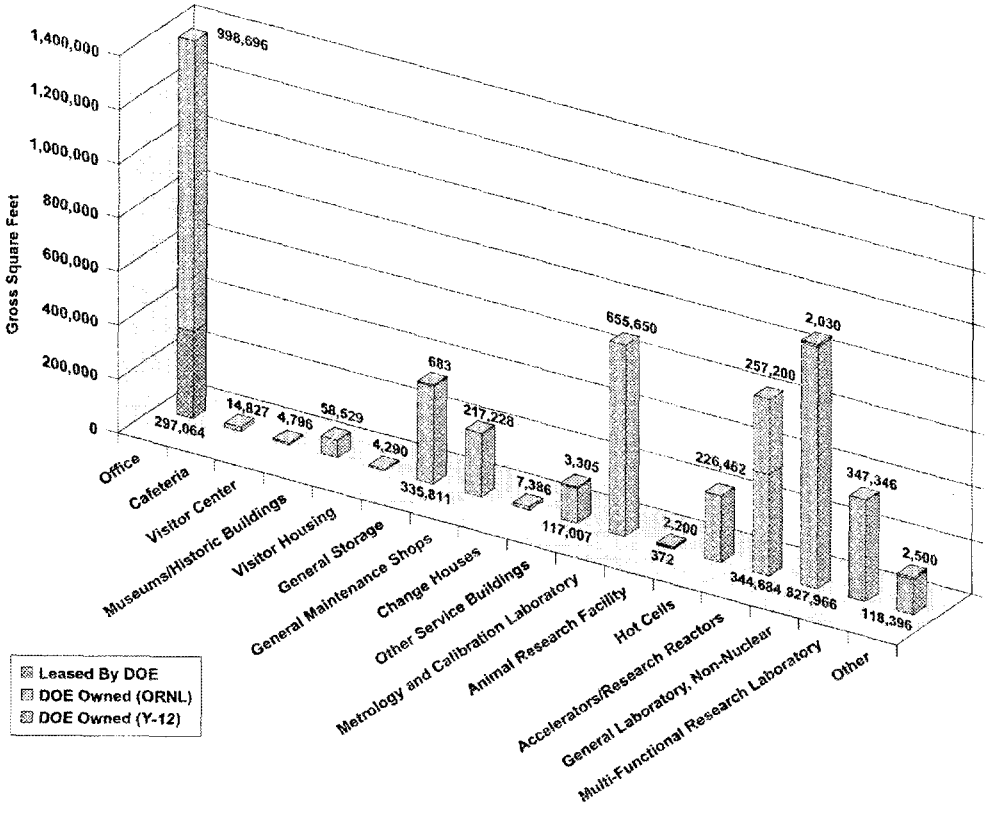

Figure 7.2
Ownership and use of ORNL space.

7.3.3 • Site and Facilities Plans

7.3.3.1 • Facilities Modernization

ORNL has established a dedicated project team, the Facilities Revitalization Project (FRP), to carry out the task of providing ORNL staff with world-class facilities, consolidated at the main Laboratory site, with the first phase of construction to be completed within five years. The project will use a combination of DOE, state of Tennessee, and private-sector funds to accomplish this task.

A project management plan was developed to provide the framework for conducting the FRP. The FRP is managed as a programmatic office, with primary resources for execution of the project to be obtained from the responsible organizations within ORNL (Engineering, Procurement, Infrastructure Planning, etc.). The project management plan includes a definition of the project scope, the organizational responsibilities, and the project approach, including a detailed Work Breakdown Structure (WBS) with three main elements: project planning basis, facility deactivation and consolidation, and new facilities development. FRP responsibilities include

- preparing the ORNL *Strategic Facilities Plan,* which outlined the overall approach of the facilities development and reuse strategy and defined the unifying architectural and best energy management practices for the new facilities;
- developing and implementing an exit strategy for nonstrategic ORNL facilities, placing those facilities in a "cheap-to-keep" mode, and transferring those facilities to the appropriate DOE program for final disposition;

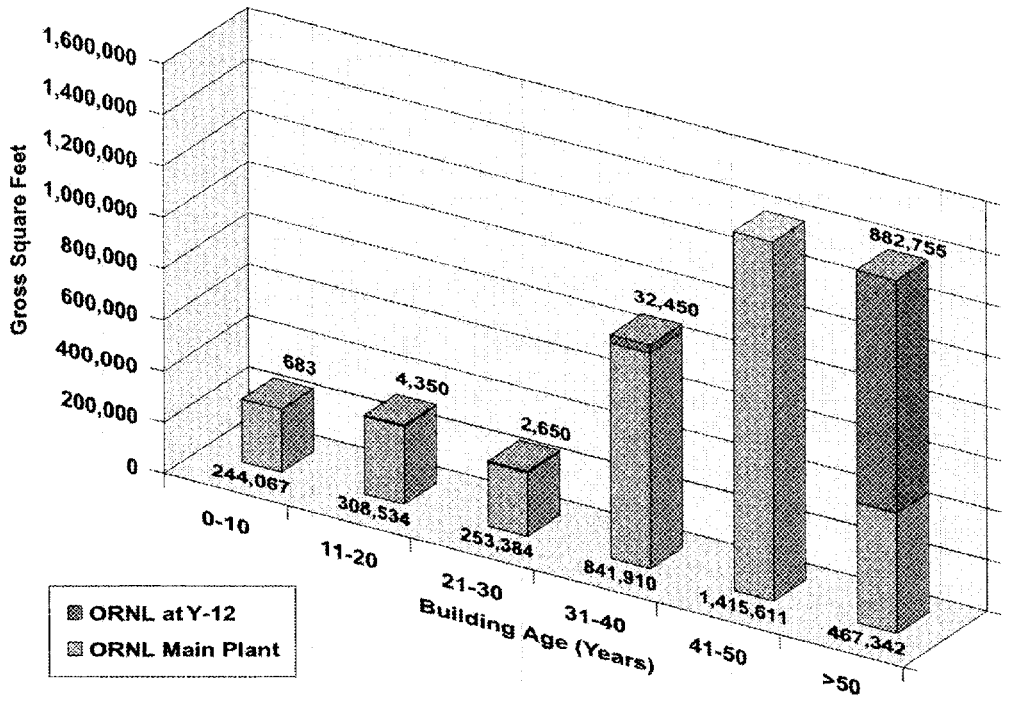

Figure 7.3
Age of ORNL buildings.

- constructing new facilities that leverage investments from DOE and the state of Tennessee; and
- acquiring new facilities through innovative approaches, using private-sector funding for construction, followed by ORNL leasing of that new space.

The overall approach to project execution is to apply a structured, but graded, process to the two major components of the FRP: consolidation of existing facilities and construction of new facilities. Current approved policies and procedures are applied for the DOE-funded portions of the project (both facility transfers and capital construction), with modifications of those processes implemented for the private-sector and state of Tennessee–financed facilities improvements, as appropriate.

ORNL has developed a Master Plan for site development that supports the Laboratory's expected mission needs during the planning period; establishes a safe, high-quality, energy-efficient work environment for research and support staff in a research campus setting; and addresses the long-term maintenance and ultimate disposition of "retired" facilities in an environmentally acceptable manner. This plan will result in the consolidation of ORNL space from the current occupied levels of more than 4.8 million square feet to just over 3.2 million square feet, with the consolidated staff residing almost exclusively at the main ORNL site. The Master Plan outlines a phased approach to facilities modernization, with the primary emphasis during the planning period placed on establishing the East Campus infrastructure, constructing and refurbishing critical mission-oriented research facilities, and moving staff from Y-12 to the main ORNL site. The second phase will include completion of the East Campus core construction, continuing consolidation of off-site staff at the main ORNL site, and primary development of the ORNL West Campus for life and environmental sciences research.

A hot cell facilities assessment conducted in FY 2001 identified a number of options for addressing ORNL's continuing needs for hot cell capabilities. These options include continuing operation of existing hot cells with necessary upgrades implemented, consolidation of operations into fewer facilities, and construction of new purpose-built facilities. The feasibility of these options continues to be addressed.

Accomplishing the Facilities Modernization Initiative in the proposed time frame will require resources beyond those normally provided by DOE capital construction programs. Therefore, the integrated construction plan includes both private-sector funding and investments by the state of Tennessee in addition to available line-item and General Plant Project (GPP) funds. An upper-level schedule outlining the major construction activities to be conducted during implementation of the Master Plan is presented in Fig. 7.4. This schedule will be refined as funding profiles, project scope, and method of accomplishment are defined by DOE.

7.3.3.2 • Facilities Management

The Enhanced Operational Discipline Initiative includes the task of upgrading the Laboratory's infrastructure and providing effective stewardship of facilities and operations resources. We have initiated the development of a management process to enhance research and support operations through facility use agreements (FUAs), building manager and facility core teams, and integrated operations. The system will define work processes and ownership, establish responsibilities and authorities, and develop continuous improvement targets for work processes.

To facilitate this initiative, FUAs are being developed and will be used to define the scope of work supported by each facility's design and operating boundaries, establish the service levels that can be expected by occupants from building service providers, and link occupant work activities within the facility to applicable policies and procedures. The link between FUAs and work control establishes a documented basis for facility-level controls tailored to level of hazard and acceptable risk, provides a basis on which to evaluate the conduct of proposed activities in terms of the recognized building work scope and operating boundaries, and drives the implementation of a documented review and change control process when work activities have the potential to exceed the operating boundary. A facility management pilot project implemented in the 4500 complex during FY 2001 provided input to the development of the facility management model and to the definition of the path forward.

The Enhanced Operational Discipline Initiative is also expected to improve ORNL maintenance requirements planning by promoting a more comprehensive, uniform approach to identifying maintenance needs. In the new ORNL facility operations model, facilities are grouped into eight complexes. A complex manager will be responsible for facility operations and maintenance in each complex. Currently, required and deferred maintenance requirments are taken from the CAIS database system. Required maintenance includes those deficiencies identified as "repair within one year" in the CAIS system. Condition assessment system inspections are nonintrusive and could miss deficiencies that are "hidden." The complex manager's complex team will be responsible for the day-to-day operation of facilities in its complex and will have a greater familiarity with facility conditions and maintenance requirements. This should enhance maintenance planning in each complex.

Maintenance costs in FY 2001 were approximately $10.9 million or 0.24% of RPV. Maintenance expenditures in FY 2002 are projected to increase to approximately $14 million or 0.31% of RPV. These costs are funded through space charges as an element of Laboratory overhead. The primary constraints on increasing maintenance funding are continuing pressure to reduce overhead rates coupled with relatively stable Laboratory base budgets.

7.3.4 • Detailed General-Purpose Facilities Plans and Facilities Resource Requirements

The key general-purpose facility issues at ORNL include (1) relocation of ORNL organizations at Y-12 to the main ORNL site, (2) upgrades and modifications to existing laboratory and experimental space to better facilitate R&D activities, (3) upgrades and replacement of site and facility utility systems, and (4) disposition of inactive/surplus facilities. These issues are being addressed through the Facilities Modernization Initiative and the Enhanced Operational Discipline Initiative (see Sect. 7.3.3).

Traditional funding sources for infrastructure modernization include GPP and general-purpose equipment (GPE) budgets, programmatic line items, and DOE's Multiprogram Energy Laboratory Facility Support (MEL-FS) Program. To meet ORNL's needs for modernization, innovative arrange-

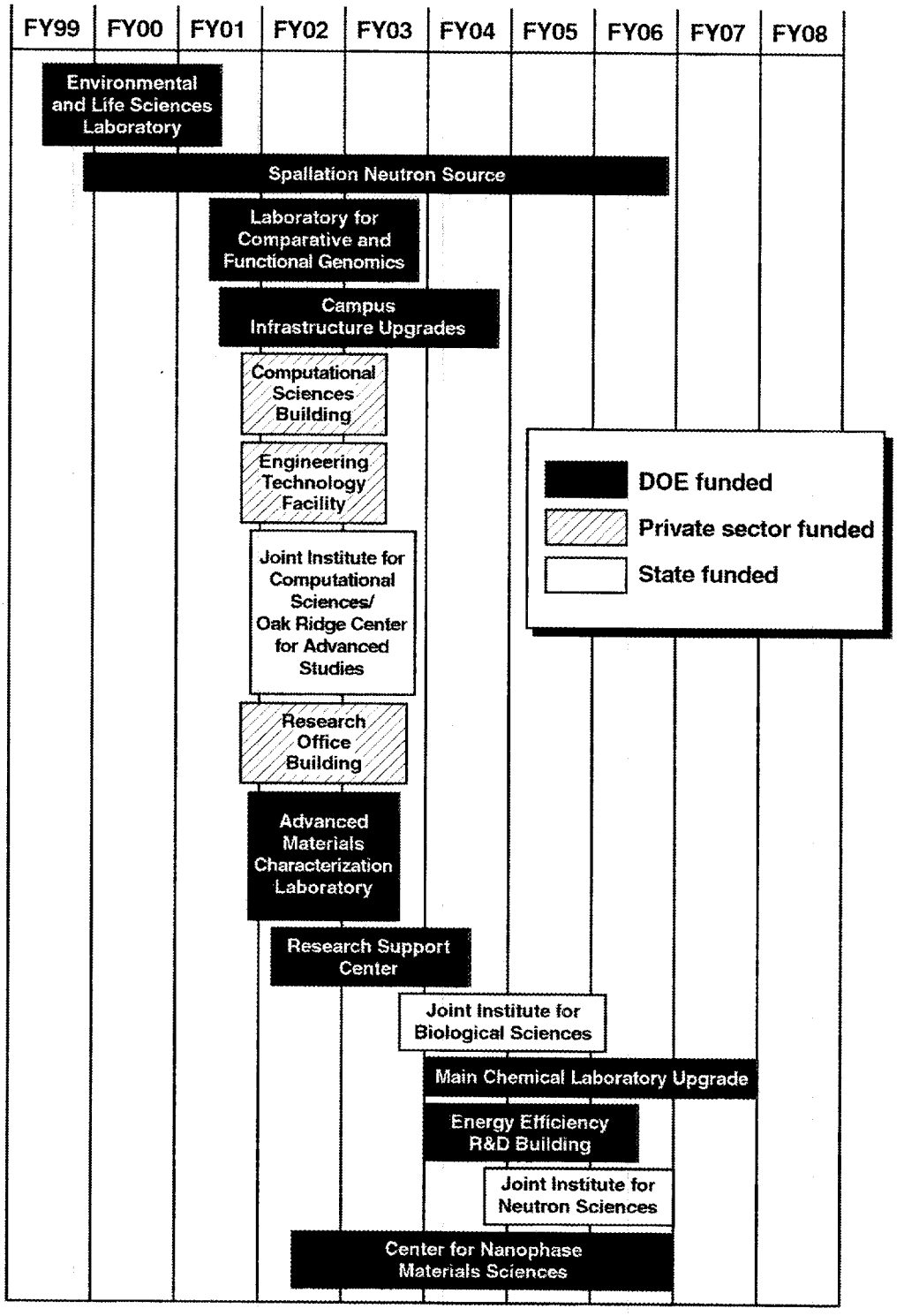

Figure 7.4
Preliminary schedule for ORNL site development.

ments have been established to add funding from the state of Tennessee and private sector funds to these sources.

Table 7.3 shows currently funded construction projects. The *ORNL Land and Facilities Plan* provides a comprehensive list of proposed construction and renovation projects. A list of projects proposed for DOE capital funding to achieve DOE-SC's vision of a 21st Century Laboratory at ORNL is presented in Table 7.4. Based on a comprehensive assessment of needs performed for the *ORNL Strategic Facilities Plan* in October 2000, an annual requirement of $20 million for landlord GPP and GPE is projected through 2010. MEL/FS line item requirements vary between $20 million and $35 million annually over the same period.

Table 7.3
Major construction projects: funded construction[a]
($ in millions—BA)

		Fiscal year			
	TEC[b]	2001	2002	2003	2004
Research Program Line Item Projects					
Accelerator and Reactor Improvements and Modifications	9.00	1.99	4.21	1.40	1.40
Spallation Neutron Source	1,411.70	258.93	276.30	210.57	124.60
Laboratory for Comparative and Functional Genomics	13.90	2.50	10.00	1.40	—
General Purpose Facility Line Item Projects					
Electrical systems upgrade	5.90	5.54	—	—	—
Fire protection system upgrade	5.92	0.58	3.12	2.22	—
Laboratory facilities HVAC upgrades	7.10	0.50	3.00	3.60	—
Research Support Center	16.10	—	1.50	5.00	9.60
General Plant Projects—Landlord					
Bethel Valley Road entrances	2.60	—	2.60	—	—
HFIR cooling tower replacement	4.05	2.25	—	—	—
Building 7602 high bay upgrade	0.85	0.20	0.65	—	—
7600 Area High Bay Building	4.50	—	0.40	2.40	1.70
Fire protection upgrades	3.60	0.58	0.05	0.80	—
East campus infrastructure improvement projects	7.22	1.53	1.77	2.46	1.46
Electrical system upgrades	0.57	0.44	0.13	—	—
Building 1061 modification	0.21	0.20	0.01	—	—
Advanced Materials Characterization Laboratory	4.80	0.56	2.00	2.24	—
Chemical Management Center, Building 7013	0.10	0.10	—	—	—
Greenhouse renovation, Buildings 1503 and 1506	1.55	—	—	0.20	1.35
Rebuild steam station 7920	0.75	—	0.15	0.60	—
Nanoscience Metrology and Instrumentation Laboratory	1.50	0.60	0.60	—	—
Total funded construction	**1,501.92**	**276.50**	**306.49**	**232.89**	**140.11**

[a]Construction data as of November 2001.
[b]TEC = total estimated cost. May include funding from prior years.

7.3.5 • Space Management and Inactive Surplus Facilities

7.3.5.1 • Space Management

ORNL's space charge system promotes effective and efficient use of ORNL buildings and equitable distribution of the costs associated with maintaining these buildings. Space charge components

Table 7.4
DOE resources needed for achieving a "21st Century Laboratory"
($ in millions—BA)

		Fiscal year				
	TEC[a]	2002	2003	2004	2005	2006
Programmatic Line Item Projects						
Center for Nanophase Materials Science	63.5	1.5	15.0	36.0	11.0	—
Energy Efficiency R&D Facility	12.0	—	12.0	—	—	—
Other Programmatic Line Items	20.0	—	—	—	2.0	14.0
Landlord Line Item Projects						
Laboratory upgrades and renovations, 4500 area	147.7	—	—	1.9	14.9	15.7
Other Line Item Projects	49.2	—	—	0.7	9.5	15.0
Programmatic General Plant Projects						
Plutonium-238 Facility Modification	3.1	3.0	0.1	—	—	—
Other Programmatic GPP	27.0	10.6	5.7	5.0	1.0	2.0
Landlord General Plant Projects						
East Campus Service Building	4.4	—	—	—	—	0.4
Central Campus Research Building	4.5	—	—	—	0.4	4.1
7900 Area Projects	5.6	—	—	0.3	2.5	—
Building 5500 Renovation	4.5	—	—	1.5	3.0	—
Other GPP/GPE	181.5	—	11.0	18.0	23.2	20.9
Total	523.0	15.1	43.8	63.4	67.5	72.1

[a]TEC = total estimated cost.

include facility planning and administration, nonprogram line item/GPP construction design, space relocation (forced), lease costs, janitors, asbestos abatement (management), building maintenance/services, HVAC maintenance, grounds maintenance, utilities on returned space, activity data sheet (ADS) requirements, In-House Energy Management, and fire protection engineering. The Space Allocation Management System (SAMS), which contains data associating a specific employee and organization with occupied space, is used for allocation of space charges. The space charge system will continue to be refined to drive greater efficiency in the use of space, supporting the aims of the Enhancing Operational Discipline Initiative. Organizations are assessed space charges based on two categories of space: (1) conditioned space at $21.60 per square foot and (2) unconditioned space at $7.20 per square foot.

As a result of space charge implementation, more than 600,000 square feet of marginal space has been vacated. Approximately 350,000 square feet of this space has been completely deactivated. Seven buildings, totaling 220,000 square feet, have been transferred to the Y-12 National Security Complex; 15,000 square feet is contaminated and will be proposed for inclusion in the EM program in FY 2002.

7.3.5.2 • Facilities Consolidation and Deactivation

The FRP is responsible for developing and implementing an exit strategy for nonstrategic ORNL facilities; transferring nonstrategic, uneconomical, or underutilized facilities that no longer support the Laboratory's mission to other parties; and placing facilities that cannot be transferred in a "cheap-to-keep" mode (i.e., a state of minimum cost, with the minimum utilities, maintenance, and surveillance) until ultimate disposition can be funded. These tasks are addressed in the FRP WBS by a Facility Consolidation and Deactivation Element.

The FRP completed an inventory of existing facilities use and conditions and developed a list of nonstrategic facilities. Two disposition paths will be used to handle facilities determined to be surplus: facility transfer and facility deactivation. Facilities on the transfer path will be transferred to another contractor for alternate use or to an entity such as the Community Reuse Organization of East Tennessee (CROET). Facilities on the deactivation path will be placed in "cheap-to-keep" mode and put

under a routine surveillance and maintenance (S&M) program. Those that meet the criteria for DOE's Environmental Management Program (DOE-EM) will be transferred to DOE-EM as soon as possible.

ORNL faces an enormous challenge in the deactivation and disposition of its nonstrategic facilities. Many of these facilities are large and complex, and some contain multiple hazards. We have identified 40 facilities, representing more than 1.1 million square feet, as candidates for disposition through DOE-EM, and 89 facilities, including a number of trailers, that would remain the responsibility of DOE-SC. The estimated cost of facilities consolidation and S&M during the time frame of the *ORNL Strategic Facilities Plan* (FY 2001–FY 2011) is $113 million. The estimated cost for ultimate D&D of ORNL's nonstrategic facilities is $126 million; under the present schedule, most D&D activities will be conducted after 2011.

7.3.6 • Energy Management

ORNL's In-House Energy Management (IHEM) program is directed toward saving energy, reducing energy costs, protecting the environment, enhancing the workplace environment, improving operations, and providing leadership in the adoption of new energy technologies. The program has yielded a 20% reduction in energy use per square foot of occupied space since 1985.

Several energy management initiatives are under way, and positive results are being realized. Key activities include the following:

- About 39,000 fluorescent lamps have been replaced with more efficient lamps; almost 21,000 ballasts have been replaced with more efficient units that do not contain polychlorinated biphenyls (PCBs); and about 900 occupancy sensors have been installed to switch off lights in empty rooms. Energy usage and costs have been reduced by 30 to 70% in the affected areas.
- ORNL continues to retire CFC chillers or replace them with high-efficiency, non-CFC chillers. To date, 16 chillers totaling 8,200 tons in cooling capacity have been replaced. As a result, chiller energy use has dropped an average of 21% for annual savings of $280,000, and CFC emissions have been cut by 5000 lb per year, saving another $76,000 annually.
- Energy management control systems have been installed in 13 buildings; this includes the installation of 19 variable-speed drives on supply and exhaust fan motors.
- Following an assessment of the energy efficiency of 16 office buildings at ORNL, 1 building has been officially designated as an Environmental Protection Agency (EPA) Energy Star® building. Documentation of the performance of the Buildings Technology Center headquarters building was submitted to the EPA, and the certification was subsequently awarded. This was one of the first DOE buildings to achieve this rating and only the second building in the state of Tennessee to do so. Electric metering is being added to 11 other candidate buildings so that they can also be evaluated for Energy Star® awards.

In addition, the conversion of the ORNL steam plant from coal to natural gas is expected to save about $1 million per year in operating costs and $8 million in capital funding over 10 years, while avoiding emissions from coal combustion.

ORNL is also pursuing energy savings performance contracting (ESPC) as a way to implement projects using the funding and support of an energy service company (ESCO). When a project is complete, the ESCO is paid back from the energy savings. Once the ESCO is paid in full, the infrastructure improvements and future energy savings belong to ORNL. The first ESPC project is nearing the construction phase, and a second, sitewide ESPC project is nearing the proposal stage.

ORNL was the first industrial participant in the Green Power Switch program established by the Tennessee Valley Authority (TVA). The program offers power produced using renewable energy sources such as sunlight, wind, and landfill gas. Although this "green power" costs more than power from traditional energy sources, it is expected to improve regional air and water quality by reducing waste and pollution. In addition, increased demand should lead to expanded power production capacity and eventually to lower costs.

8 • Community Service

UT-Battelle's commitment to excellence in community service includes three Laboratory-level initiatives (see Sect. 3.2) designed to broaden access to the extensive scientific and technological assets of the Oak Ridge National Laboratory (ORNL) and to leverage these resources to the benefit of the region. This commitment will be demonstrated through partnerships with the region's business community; schools, colleges, and universities; and economic development groups and through a public awareness program focused on local and regional stakeholders.

8.1 • Technology Transfer and Economic Development

Our Economic Development Initiative supports the creation and growth of businesses that will enhance the local and regional economy by drawing on ORNL resources in knowledge and technology and on UT-Battelle investments in economic development.

The ORNL Technology Transfer and Economic Development organization comprises the Office of Technology Transfer and the Office of Economic Development.

8.1.1 • Technology Transfer

The Office of Technology Transfer is responsible for managing collaborations and access to ORNL resources and personnel through cooperative research and development agreements (CRADAs), technology licensing, and user facility programs. This office also manages and protects ORNL's intellectual property, leveraging this resource to increase its value through private-sector partnerships to promote the commercialization of innovations based on programmatic research and development (R&D) funded by the Department of Energy (DOE). More than 70% of this commercialization has been undertaken by small businesses. About one-third of the commercialization has resulted in the creation of start-up companies, more than 65% of which are located in East Tennessee.

CRADAs, licenses, and Work for Others (WFO) agreements are the main vehicles by which ORNL establishes partnerships with the private sector. These mechanisms enable transfer of Laboratory technology for commercialization and leverage DOE programmatic funding with funds in from the private sector. During FY 2000, 24 new CRADAs were established, 7 option agreements were executed, and 21 licenses were executed.

As DOE funding for CRADAs has decreased over the past five years, the number of private partners directly funding collaborative R&D has increased. Private-sector partners provide significant support to leverage programmatic funding for technology transfer, with more than $22 million in funds in to ORNL.

ZeTek, a leading international manufacturer of fuel cells, is starting up a production facility in East Tennessee, building on technology developed at ORNL. At the heart of ZeTek's alkaline fuel cell system will be ORNL's carbon fiber molecular sieve, enabling robust systems that are inexpensive to operate. ZeTek will also use ORNL's electrical swing adsorption, a technique that involves passing an electric current through the carbon fiber base material to rid it of the carbon dioxide captured from the fuel or oxidant. ZeTek will target the power generation industry, which can use fuel cells to help replace fossil fuels, which are less environmentally friendly. ZeTek expects to be able to show that its systems are competitive with gas-fired generation of electricity.

Some partnerships involve both licenses and CRADAs. ORNL's patented nonlinear condition monitoring technology has been licensed to Nicolet Biomedical, Inc., of Madison, Wisconsin, for application in a product to detect and predict the onset of epileptic seizures in humans. Under a related CRADA between ORNL and Nicolet Biomedical, researchers are developing a system that would

provide an 8- to 50-minute warning before an epileptic seizure, giving a person time to take appropriate action. Graviton, Inc., of San Diego, California, has licensed microcantilever technology and radio-frequency wireless communications technology to produce sensors for use in drug discovery, clinical diagnostics, chemical detection, and physical sensing. Under a 100% funds-in CRADA, Graviton is expected to provide more than $4 million of R&D funding to ORNL over a period of three years.

User facility programs support access to ORNL's distinctive capabilities. User agreements between ORNL and outside organizations stipulate terms and conditions for use of the Laboratory's designated user facilities. More than 600 agreements are in place with universities, private companies, and other research institutions. In FY 2000, 50 new academic and industrial user agreements were signed, and 139 new projects were initiated under existing agreements.

Opportunities for industry have been expanded with the designation of two national user facilities: the Power Electronics and Electric Machinery Center (PEEMRC) and the National Transportation Research Center (NTRC). The PEEMRC is a broad-based research center for power electronic inverters and electric machinery development. It has dramatically advanced the technology of soft-switched inverters, multilevel inverters, motor control techniques, and efficient, compact electric machines. The NTRC (see Sect. 5.2.1) provides the public and private sectors with state-of-the-art knowledge, facilities, and technologies for the development and deployment of cost-effective transportation systems.

ORNL is an active partner in several consortia, including the Partnership for a New Generation of Vehicles (PNGV), which supports cooperative projects involving programs in the DOE Office of Energy Efficiency and Renewable Energy (DOE-EE), the DOE Office of Science, and the Office of the Deputy Administrator for Defense Programs within DOE's National Nuclear Security Administration. ORNL is also pursuing the implementation of partnerships with companies and consortia representing the industries participating in the DOE-EE Industries of the Future initiative.

Research staff members at ORNL generated 97 new invention disclosures, and the Office of Technology Transfer elected to request patent rights from DOE on 62 of these disclosures. The Office of Technology Transfer filed 71 patent applications during FY 2000.

8.1.2 • Economic Development

ORNL supports DOE's efforts to advance the nation's economic security by encouraging the use of DOE resources to address manufacturing problems and promote the creation of new businesses. In pursuit of this goal, the Laboratory is strengthening its partnerships with state and regional economic development groups.

- ORNL is promoting a broader program of technology transfer through the Center for Entrepreneurial Growth, a partnership with Technology 2020 of Oak Ridge.
- ORNL is broadening its role in industrial outreach through closer partnerships with the Tennessee Department of Economic and Community Development, Technology 2020, and the chambers of commerce in Oak Ridge, Anderson County, Roane County, and Knox County.
- ORNL's Small Business Program Office serves as the focal point for procurement opportunities and projects supporting small businesses (including minority-owned, women-owned, and veteran-owned concerns). Among these efforts is DOE's Mentor-Protégé Program.

The National Transportation Research Center (see Sect. 5.2.1 of the Institutional Plan) represents a regional economic development effort involving DOE, UT-Battelle, the University of Tennessee (UT), and the Development Corporation of Knox County (TDC). Each party brings important assets to the relationship. ORNL, as a DOE national laboratory managed by UT-Battelle, has extensive scientific and technical capabilities plus a funding base of nearly $80 million in transportation R&D from multiple sponsors. UT brings nationally recognized R&D programs in transportation logistics and advanced vehicle technologies with a funding base approaching $20 million. TDC assisted in helping to build the facility, provided the site for the Center, and will assist in identifying companies wishing to access the advanced user facilities and the collective R&D expertise.

Approximately $500,000 of UT-Battelle's annual corporate fee is directed to fund technology transfer, venture capital, and industry recruitment programs. In addition, UT-Battelle is promoting

expanded corporate investment by providing access to a $100 million venture capital fund network to assist start-up companies.

During the first half of FY 2001, 8 new businesses based on ORNL technology have been created, and the Technology Transfer and Economic Development Directorate has provided assistance to 12 businesses, including 10 small businesses.

DOE's Mentor-Protégé Program provides a mechanism for contractors to enter into integrated working relationships with and provide nonfinancial assistance to energy-related small, disadvantaged, and women-owned businesses to enhance their business and technical capabilities. In February 1998, ORNL became the first DOE national laboratory to participate in this program by signing a mentor-protégé agreement with Advanced Integrated Management Services, Inc. (AIMSI). Under the terms of the agreement, ORNL mentors AIMSI in a number of areas. Subcontracting activities are provided by ORNL's Chemical Sciences and Engineering divisions for project management support. Training is provided as needed to enhance and strengthen AIMSI's technical and business capabilities.

UT-Battelle is also working to encourage more interaction with small businesses. Much of this activity is expected to occur in the technical assistance area, with support from DOE's Laboratory Technology Research assistance program.

At the request of DOE, the Small Business Program Office served as co-lead for the second annual national DOE Small Business Conference, held in Las Vegas in June 2001. On-site briefings have been provided to 15 highly technical small businesses, and a briefing package, "Doing Business with ORNL," has been prepared. A Web-based listing of procurement opportunities is now available, and the Historically Black Colleges and Universities/Minority Educational Institutions (HBCU/MEI) Outreach Initiative described in Sect. 8.2.2 includes an emphasis on subcontracting with these institutions. In August 2001, ORNL received a Tennessee Small Business Advocacy Award.

ORNL is working with other Battelle partner laboratories to share small business supplier databases. The subcontract for the new managed hardware and software program (see Sect. 7.2.4) will be a small business set-aside, and Accelerated Vendor Inventory Delivery (AVID) subcontracts are being targeted for small businesses.

8.2 • Education Partnerships

ORNL's education partnerships support DOE's commitment to effective programs for science education. The focus is on improving science and mathematics teaching skills and providing learning opportunities for faculty and students.

Through its Communications and Community Outreach (C&CO) directorate, ORNL coordinates and funds a variety of programs that engage students and faculty in research, training, and collaboration. As these programs expose participants to quality science and mathematics teaching and learning, they increase the number and diversity of high-achieving students introduced to research opportunities and potential careers at ORNL.

Several programs support our Science and Mathematics Education Initiative. The programs are designed to identify ORNL and DOE with the state of Tennessee's emphasis on improving mathematics and science learning among the state's K–12 students. In FY 2001, UT-Battelle provided five area schools with state-of-the-art science laboratories valued at $10,000 each. UT-Battelle has also become the primary sponsor of the UT Academy for Teachers of Science and Mathematics, implementing an emphasis on training larger numbers of Tennessee middle school teachers. New scholarships have been funded for minority students in the UT College of Engineering and for high-achieving children of ORNL employees who attend UT and major in science or mathematics. ORNL's support of science and mathematics education has been further strengthened through the underwriting of regional, state, and national science and engineering competitions.

ORNL annually hosts several thousand students for educational experiences. Statistics on program participation are included in the Supplemental Information appended to this report. Some participate in short programs, such as those available for K-12 students through the Ecological and Physical Sciences

Study Center. Other students spend longer periods conducting research through programs such as the DOE Energy Research Laboratory Undergraduate Fellowships, the Great Lakes Colleges Association Oak Ridge Science Semester, or postdoctoral fellowships sponsored by ORNL or DOE. In FY 2001, ORNL partnered with the Oak Ridge Institute for Science and Education (ORISE) to coordinate many of these educational experiences.

8.2.1 • Pre-College Partnerships

In its K–12 education programs, ORNL emphasizes hands-on, engaged learning activities for both students and teachers. Programs are designed to develop scientific habits and help prepare students and teachers to be proactive in science, math, and technology education.

The Ecological and Physical Sciences Study Center, one of ORNL's most visible activities, presents 37 instructional modules. Classes can be presented either at the historic Freels Bend cabin on the Oak Ridge Reservation or at schools or other locations. The Study Center now operates year-round, including summer science camps for middle school students and teacher workshops that transfer course content for classroom use. The ECOEDge program enables middle school and high school students to conduct research on parts of the Oak Ridge National Environmental Research Park. A continuing effort is made to reach students with physical and/or sensory disabilities. Classes and presentations are also offered to groups outside the academic arena (e.g., garden clubs, senior citizen groups, and Scouting groups).

8.2.2 • Higher Education Partnerships

In addition to the educational opportunities afforded by its research partnerships with universities (see Sect. 6.2), ORNL develops partnerships with colleges and universities that complement and extend the resources available in an academic setting.

The UT-ORNL Graduate School in Genome Science and Technology offers a unique and multidisciplinary program for full-time graduate study leading to a Ph.D. or M.S. degree in this emerging field. The program takes advantage of interaction and collaboration among scientists at ORNL and faculty at UT, in conjunction with the Joint Institute of Biological Sciences (see Sect. 4.2.6). Courses and research opportunities are available at both locations, and research projects are mentored by a UT faculty member and an ORNL staff member. Other UT programs that draw on ORNL resources include the Graduate Program in Ecology and the Joint Program in Mixed-Signal VLSI and Monolithic Sensors. The UT Department of Physics and Astronomy also maintains close research relationships with ORNL; a new collaboration is creating enrichment materials in astronomy for use in K–12 classrooms.

ORNL is one of six multiprogram laboratories participating in the DOE Institute of Biotechnology, Environmental Science, and Computing for Community Colleges. The program provides educational training and research experience for highly motivated community colleges students through a summer institute for selected students.

ORNL is working to increase its interactions with historically black colleges and universities (HBCUs) and other minority educational institutions (MEIs) through mechanisms such as the DOE Science and Technology Alliance, the Waste Management Consortium, the National Consortium for Graduate Degrees for Minorities in Engineering, Inc. (GEM Consortium), the Consorcio Educativo para la Proteccion Ambiental (CEPA), and the Advanced Industrial Concepts Materials Fellowship Program. The Laboratory has established a formal HBCU/MEI outreach initiative that includes the following components:

- an HBCU/MEI ORNL Senior Management Team,
- an HBCU/MEI summer research program (see Sect. 6.3),
- outreach programs that encourage visits to HBCU/MEI campuses, and
- student internships.

8.3 • Public Awareness and Community Outreach

ORNL's Community Involvement Initiative drives an outreach program guided by the desire to be viewed by our neighbors as a highly valued member of the community and the region. The program includes financial contributions to a variety of educational, civic, cultural, and economic development activities. In addition, the UT-Battelle Leadership Team participates in a number of volunteer activities and actively encourages the participation of Laboratory employees. Outreach initiatives, as well as issues affecting the Laboratory's scientific direction, are incorporated into a communications strategy for employees and external stakeholders. Communications activities are designed to provide a sense of inclusion to employees about the Laboratory's goals and activities. For external stakeholders, the goal is increased visibility and understanding of ORNL's mission, leading to a similar increase in public support for the Laboratory's role as a trusted regional asset.

8.3.1 • Outreach Activities

Community outreach activities provide opportunities to support DOE's commitment to building and maintaining public trust. Such activities also offer the chance to increase ORNL's visibility, broaden the understanding of the Laboratory's scientific programs and direction, and demonstrate ORNL's value to the community and the region. Many of ORNL's outreach activities are built around the themes of educational, civic, cultural, and economic development partnerships.

- Team UT-Battelle has been created to provide coordination and funding for employee volunteer activities, including participation in Habitat for Humanity builds. Five projects have been launched, and several more are being organized.
- Contributions from employees and UT-Battelle represent a large share of funds collected in the region's annual United Way campaigns. Many employees volunteer their time to United Way and to other charitable and civic programs.
- ORNL works closely with the American Museum of Science and Energy, providing financial and management assistance for a variety of educational and cultural programs at this important regional attraction.
- The ORNL Speakers Bureau provides opportunities for leading researchers to share information about DOE's missions with civic, educational and business groups throughout Tennessee.
- UT-Battelle is a leading sponsor of civic and cultural activities in the Oak Ridge area, including the Oak Ridge Symphony and the Oak Ridge Arts Council, the League of Women Voters, and the National Association for the Advancement of Colored People.

ORNL's historic Graphite Reactor and the New Bethel Church Interpretive Center are open to the public as part of a self-guided driving tour. Both facilities are featured on the Tennessee Heritage Trail listing developed by the state's Department of Tourist Development. ORNL C&CO staff helped initiate the use of the "Touch & Go" interactive information screens used at six Tennessee welcome centers to help inform travelers about ORNL visitor attractions. The Graphite Reactor hosted more than 9,100 visitors in FY 2000.

C&CO staff also provided 39 special orientation tours or customized tours for 1,293 visitors to the Laboratory and supported the Oak Ridge ORNL/Y-12 Plant Public Tour. This tour, which originates at the American Museum of Science and Energy in the city of Oak Ridge, is available from March through October. In FY 2000, it served 1,838 visitors. More than 12,000 visitors from all 50 states and 58 other nations have visited ORNL through the public tour, which is included on the Tennessee Heritage Trail.

These activities serve to educate local, regional and national groups about DOE activities in the Oak Ridge area. They are also expected to help increase science literacy and to provide feedback on how ORNL is perceived by the public.

Information about the environment of the Oak Ridge Reservation is disseminated to the public, and the public is involved in decisions concerning management of the reservation. Public education activities at the Oak Ridge National Environmental Research Park include special events, such as wildflower hikes and bird walks, and "hands-on" experiences for precollege students.

ORNL's scope of work includes the management of the American Museum of Science and Energy (AMSE). The Laboratory works with DOE and Enterprise Advisory Systems, Inc., which operates the museum under subcontract to UT-Battelle, to strengthen public awareness of DOE programs and activities.

A plan to ensure the financial stability of the museum was completed early in FY 2001 and submitted to DOE. With support from UT-Battelle, legislation that makes it possible for AMSE to charge admission fees, accept private donations, and implement other revenue-generating mechanisms has been enacted by Congress. The museum's hours of operation have been reduced to lower the cost of operations while still serving the maximum number of visitors, and admission fees are now being collected. Discussions are under way to effect the transfer of the AMSE facility and property to the City of Oak Ridge as a key step in ensuring the viability of this important resource.

C&CO staff provide support and planning for community activities and special events. At ORNL, the Protocol Office hosted or provided support for visitors including the Secretary of Energy; Don Sundquist, governor of Tennessee; Gen. Henry H. Shelton, chairman of the Joint Chiefs of Staff; several members of Congress; the Battelle Memorial Institute Board of Trustees; and numerous other dignitaries.

The new visitor center in Building 5002 provides visitors to ORNL with an appropriate introduction to the Laboratory, its history, and its programs. Plans are being made to broaden ORNL's community outreach activities and continue to improve the flow of information to employees.

8.3.2 • Communication Activities

UT-Battelle's efforts to have the public view ORNL as a highly valued asset include a variety of communication initiatives with internal and external stakeholders. The goal of the ORNL C&CO directorate is to provide stakeholders with a better understanding of what ORNL does and the positive impact of the Laboratory Agenda.

- The *ORNL Today* daily update on the Laboratory's internal Web server is viewed by employees more than 5,000 times each week.
- The *ORNL Reporter*, a newsletter that highlights Laboratory activities, is delivered monthly to employees and retirees and is available on the external Web server.
- The *ORNL Review*, an illustrated in-depth look at some of ORNL's efforts in scientific research, is published three times a year and distributed to employees and others with an interest in the Laboratory's activities. In 2001, the *Review* received an award of excellence in the International Technical Publications Competition sponsored by the Society for Technical Communication. The *Review* is also available on the external Web server.

These communication vehicles, combined with all-hands meetings, senior staff meetings, and a system of Laboratory-wide electronic mail, provide frequent, timely information about the nature and purpose of ORNL policies and programs.

The Laboratory's external relations program is designed to enhance ORNL's visibility among the public, media representatives, elected officials, and other stakeholders. In FY 2001, the Laboratory Director provided interviews to CNN, *Business Week*, *Newsweek*, and the *Atlanta Journal-Constitution*. Information about ORNL activities and their significance is provided to media representatives through the distribution of news releases, through telephone and face-to-face contacts made by ORNL C&CO staff, and through regular updates of ORNL's home page and news page on the World Wide Web. Awareness of ORNL and its missions is further enhanced in Knoxville, Nashville, and Chattanooga through the purchase of radio spots that reach an audience of approximately 130,000 persons.

More than 300 contacts with media representatives were made in FY 2000, and some 30 news releases were produced during this period. National and international media outlets publishing or broadcasting stories about ORNL included *Business Week*, *Chemical Engineering*, *National Geographic*, *USA TODAY*, the *New York Times*, the *London Mail*, the Associated Press, CNN, and National Public Radio.

9 • Resource Projections

Resource projections are presented in the following tables:

- Table 9.1, Laboratory funding summary,
- Table 9.2, Laboratory personnel summary,
- Table 9.3, funding by assistant secretarial level office, and
- Table 9.4, personnel by assistant secretarial level office.

These projections are based on funding requested in the FY 2002 budget submission documents, with some adjustments for subsequent guidance. They include some funding for construction that supports the major laboratory initiatives proposed in Sect. 4. In particular, capital equipment and construction funding estimates are provided for the Spallation Neutron Source (SNS).

In Tables 9.1 and 9.3, 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 9.2 and 9.4 are given as the number of full-time equivalent (FTE) employees.

Additional detail is provided in the Supplemental Information appended to this report.

Table 9.1
Laboratory funding summary by fiscal year
($ in millions—BA)

	2000	2001	2002	2003	2004	2005	2006
DOE effort	461.4	511.0	474.8	505.7	523.3	554.8	542.7
Work for others	80.1	84.7	87.0	88.8	79.8	79.8	79.8
Total operating	541.5	595.7	561.8	594.5	603.1	634.6	622.5
Capital equipment (excluding SNS)	16.0	15.7	10.7	12.1	11.7	11.8	11.8
Capital equipment, SNS	0.2	0.1	0.1	0.0	0.0	0.0	0.0
Capital equipment, Landlord GPE[a]	3.3	1.9	1.4	4.0	5.0	5.0	5.0
Construction (excluding SNS)	3.9	11.1	26.0	16.8	8.6	4.0	4.5
Construction, Landlord GPP[b]	4.4	5.8	6.4	12.0	15.0	15.0	15.0
SNS construction	100.0	258.9	218.2	210.6	124.6	79.8	41.1
Total ORNL	669.3	889.2	824.6	850.0	768.0	750.2	699.9
Proposed construction	—	—	—	26.3	50.3	36.5	32.9
Total projected funding			824.6	876.3	818.3	786.7	732.8

[a]GPE = General Plant Equipment.
[b]GPP = General Plant Project.

Table 9.2
Laboratory personnel summary by fiscal year
[Full-time equivalent (FTE) employees]

	2000	2001	2002	2003	2004	2005	2006
Technical personnel, direct DOE effort	1601.5	1909.6	1683.7	1670.8	1670.8	1670.8	1670.8
Technical personnel, Work for Others	306.8	189.5	184.7	161.1	159.4	159.4	159.4
Total technical direct personnel	1908.3	2099.1	1868.4	1831.9	1830.2	1830.2	1830.2
Other direct	300.1	352.0	355.7	355.3	355.3	355.3	355.3
Total direct personnel	2208.4	2451.2	2224.1	2187.2	2185.5	2185.5	2185.5

Table 9.3

Funding by assistant secretarial level office by fiscal year

($ in millions—BA)

	2000	2001	2002	2003	2004	2005	2006
Undersecretary for Energy, Science, and the Environment							
Office of Science							
Operating expense	173.1	195.0	180.2	190.8	199.5	219.3	223.5
Capital equipment	11.5	10.1	4.9	8.2	7.8	7.9	7.9
Capital equipment, Landlord GPE[a]	3.3	1.9	1.4	4.0	5.0	5.0	5.0
Capital equipment, SNS	0.2	0.1	0.1	0.0	0.0	0.0	0.0
Construction (excluding SNS)	3.9	11.1	23.0	16.7	8.6	4.0	4.5
Construction, Landlord GPP[b]	4.4	5.8	6.4	12.0	15.0	15.0	15.0
SNS construction	100.0	258.9	218.2	210.6	124.6	79.8	41.1
Proposed construction	0.0	0.0	0.0	13.6	50.3	36.5	32.9
Total program	296.4	482.9	434.2	455.9	410.8	367.5	329.9
Office of Energy Efficiency and Renewable Energy							
Operating expense	110.1	118.6	124.8	115.0	115.0	115.0	115.0
Capital equipment	5.1	5.2	2.2	0.6	0.6	0.6	0.6
Construction	0.0	0.0	0.0	12.0	0.0	0.0	0.0
Total program	115.2	123.8	127.0	127.6	115.6	115.6	115.6
Office of Nuclear Energy, Science and Technology							
Operating expense	17.7	19.0	19.5	40.1	58.2	67.9	51.6
Capital equipment	(0.3)	0.1	0.1	0.1	0.1	0.1	0.1
Construction	0.0	0.0	3.0	0.1	0.0	0.0	0.0
Total program	17.4	19.1	22.6	40.3	58.3	68.0	51.7
Office of Fossil Energy							
Total operating	11.4	12.3	10.0	11.4	11.8	11.7	11.7
Energy Information Administration							
Total operating	0.0	0.1	(0.1)	0.0	0.0	0.0	0.0
Office of Environmental Management							
Total operating	25.1	32.2	28.7	29.2	28.7	28.7	28.7
Capital equipment	(0.2)	0.2	0.2	0.2	0.2	0.2	0.2
Total program	24.9	32.4	28.9	29.4	28.9	28.9	28.9
Office of Civilian Radioactive Waste Management							
Total operating	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Undersecretary for National Nuclear Security							
Deputy Administrator for Defense Programs							
Total operating	18.6	18.7	21.1	22.9	23.6	24.3	25.1
Capital equipment	(0.1)	0.0	3.3	3.0	3.0	3.0	3.0
Proposed construction	0.0	0.0	0.0	0.7	0.0	0.0	0.0
Total program	18.5	18.7	24.4	26.6	26.6	27.3	28.1
Deputy Administrator for Defense Nuclear Nonproliferation							
Total operating	10.7	25.6	8.0	12.5	11.0	12.0	11.0
Capital equipment	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Total program	10.7	25.7	8.0	12.5	11.0	12.0	11.0
Departmental Staff and Support Offices							
Office of Environment, Safety and Health							
Total operating	2.2	2.0	2.1	1.5	1.4	1.5	1.4
Office of Counterintelligence							
Total operating	1.8	1.3	1.4	1.4	1.4	1.4	1.4

Table 9.3 (continued)

Funding by assistant secretarial level office by fiscal year

($ in millions—BA)

	2000	2001	2002	2003	2004	2005	2006
Office of Security and Emergency Operations							
Total operating	0.1	3.0	6.7	8.1	8.4	8.7	9.0
Office of International Affairs							
Total operating	0.0	0.2	0.1	0.2	0.2	0.2	0.2
Office of Policy							
Total operating	(0.1)	0.1	0.0	0.0	0.0	0.0	0.0
Office of Chief Financial Officer							
Total operating	0.6	0.0	0.1	0.0	0.0	0.0	0.0
Office of Worker and Community Transition							
Total operating	3.4	2.2	(0.4)	0.0	0.0	0.0	0.0
Federal Energy Regulatory Commission							
Total operating	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Environmental Management (Bechtel Jacobs Company LLC)							
Total operating	26.1	20.0	18.0	18.0	18.0	18.0	18.0
Subtotal DOE Programs							
Total operating	400.9	450.3	420.2	451.1	477.2	508.7	496.6
Capital equipment (excluding SNS)	16.0	15.7	10.7	12.1	11.7	11.8	11.8
Capital equipment, Landlord GPE	3.3	1.9	1.4	4.0	5.0	5.0	5.0
Capital equipment, SNS	0.2	0.1	0.1	0.0	0.0	0.0	0.0
Construction (excluding SNS)	3.9	11.1	26.0	16.8	8.6	4.0	4.5
Construction, Landlord GPP	4.4	5.8	6.4	12.0	15.0	15.0	15.0
SNS construction	100.0	258.9	218.2	210.6	124.6	79.8	41.1
Proposed construction	0.0	0.0	0.0	26.3	50.3	36.5	32.9
Total	528.7	743.8	683.0	732.9	692.4	660.8	606.9
DOE Contractors and Operations Offices							
Total operating	53.5	51.7	48.5	48.5	40.0	40.0	40.0
Cooperative R&D Agreements							
Total operating	7.0	9.0	6.1	6.1	6.1	6.1	6.1
Total DOE Programs							
Total operating	461.4	511.0	474.8	505.7	523.3	554.8	542.7
Capital equipment (excluding SNS)	16.0	15.7	10.7	12.1	11.7	11.8	11.8
Capital equipment, Landlord GPE	3.3	1.9	1.4	4.0	5.0	5.0	5.0
Capital equipment, SNS	0.2	0.1	0.1	0.0	0.0	0.0	0.0
Construction (excluding SNS)	3.9	11.1	26.0	16.8	8.6	4.0	4.5
Construction, Landlord GPP	4.4	5.8	6.4	12.0	15.0	15.0	15.0
SNS construction	100.0	258.9	218.2	210.6	124.6	79.8	41.1
Proposed construction	0.0	0.0	0.0	26.3	50.3	36.5	32.9
Total	589.2	804.5	737.6	787.5	738.5	706.9	653.0
Work for Others							
Nuclear Regulatory Commission							
Operating expense	8.1	7.8	7.3	6.8	6.5	6.5	6.5
Department of Defense							
Operating expense	33.5	31.4	31.2	31.3	20.4	20.6	19.0
National Aeronautics and Space Administration							
Operating expense	4.8	4.0	6.4	6.6	3.6	3.6	3.6

Table 9.3 (continued)

Funding by assistant secretarial level office by fiscal year

($ in millions—BA)

	2000	2001	2002	2003	2004	2005	2006
Department of Health and Human Services							
Operating expense	2.1	1.6	0.8	1.0	1.0	0.8	0.8
Environmental Protection Agency							
Operating expense	4.2	5.1	4.0	3.9	3.1	3.2	3.4
National Science Foundation							
Operating expense	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Federal Emergency Management Agency							
Operating expense	0.4	0.8	0.8	0.8	0.8	0.8	0.8
Department of Transportation							
Operating expense	7.1	5.6	7.4	7.4	4.6	4.6	4.6
Other Federal agencies							
Operating expenses	4.9	3.2	7.1	7.2	25.0	24.9	26.3
Electric Power Research Institute							
Operating expense	1.0	0.7	1.4	1.4	0.1	0.1	0.1
Other nonfederal agencies							
Operating expense	14.0	24.5	20.6	22.4	14.7	14.7	14.7
Total Work for Others							
Operating expense	80.1	84.7	87.0	88.8	79.8	79.8	79.8
Total ORNL							
Operating expense	541.5	595.7	561.8	594.5	603.1	634.6	622.5
Capital equipment (excluding SNS)	16.0	15.7	10.7	12.1	11.7	11.8	11.8
Capital equipment, SNS	0.2	0.1	0.1	0.0	0.0	0.0	0.0
Capital equipment, Landlord GPE	3.3	1.9	1.4	4.0	5.0	5.0	5.0
Construction (excluding SNS)	3.9	11.1	26.0	16.8	8.6	4.0	4.5
Construction, Landlord GPP	4.4	5.8	6.4	12.0	15.0	15.0	15.0
SNS construction	100.0	258.9	218.2	210.6	124.6	79.8	41.1
Proposed construction	0.0	0.0	0.0	26.3	50.3	36.5	32.9
Total	669.3	889.2	824.6	876.3	818.3	786.7	732.8

[a]GPE = General Plant Equipment.

[b]GPP = General Plant Project.

Table 9.4

Personnel by assistant secretarial level office by fiscal year

[Full-time equivalent (FTE) employees]

	2000	2001	2002	2003	2004	2005	2006
Undersecretary for Energy, Science, and Environment							
Office of Science							
Technical personnel	576.2	668.9	617.7	610.5	610.5	610.5	610.5
Other direct personnel	132.4	132.9	124.5	127.2	127.2	127.2	127.2
Total direct personnel	708.6	801.8	742.2	737.7	737.7	737.7	737.7
Office of Energy Efficiency and Renewable Energy							
Technical personnel	307.8	320.7	321.9	306.8	306.8	306.8	306.8
Other direct personnel	20.3	24.7	24.5	20.2	20.2	20.2	20.2
Total direct personnel	328.1	345.4	346.4	327.0	327.0	327.0	327.0
Office of Nuclear Energy, Science and Technology							
Technical personnel	53.0	61.9	86.4	100.8	100.8	100.8	100.8
Other direct personnel	9.3	12.9	11.9	13.4	13.4	13.4	13.4
Total direct personnel	62.3	74.8	98.3	114.2	114.2	114.2	114.2
Office of Fossil Energy							
Technical personnel	47.5	118.4	45.5	38.6	38.6	38.6	38.6
Other direct personnel	12.2	14.9	10.2	5.7	5.7	5.7	5.7
Total direct personnel	59.7	133.3	55.7	44.3	44.3	44.3	44.3
Energy Information Administration							
Technical personnel	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Office of Environmental Management							
Technical personnel	86.4	94.1	83.9	86.0	86.0	86.0	86.0
Other direct personnel	17.5	16.8	15.0	12.6	12.6	12.6	12.6
Total direct personnel	103.9	111.0	98.9	98.6	98.6	98.6	98.6
Office of Civilian Radioactive Waste Management							
Technical personnel	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Undersecretary for National Nuclear Security							
Deputy Administrator for Defense Programs							
Technical personnel	70.8	57.2	64.5	76.4	76.4	76.4	76.4
Other direct personnel	22.8	22.6	25.5	27.2	27.2	27.2	27.2
Total direct personnel	93.6	79.8	90.0	103.6	103.6	103.6	103.6
Deputy Administrator for Defense Nuclear Nonproliferation							
Technical personnel	19.4	196.1	66.7	63.6	63.6	63.6	63.6
Other direct personnel	0.0	2.9	1.0	1.0	1.0	1.0	1.0
Total direct personnel	19.4	199.0	67.7	64.6	64.6	64.6	64.6
Departmental Staff and Support Offices							
Office of Environment, Safety and Health							
Technical personnel	23.8	9.7	9.5	7.7	7.7	7.7	7.7
Other direct personnel	0.2	0.1	0.1	0.1	0.1	0.1	0.1
Total direct personnel	24.0	9.8	9.6	7.8	7.8	7.8	7.8

Table 9.4 (continued)

Personnel by assistant secretarial level office by fiscal year

[Full-time equivalent (FTE) employees]

	2000	2001	2002	2003	2004	2005	2006
Office of Counterintelligence							
Technical personnel	11.7	9.2	9.9	10.1	10.1	10.1	10.1
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	11.7	9.2	9.9	10.1	10.1	10.1	10.1
Office of Security and Emergency Operations							
Technical personnel	0.3	0.3	38.0	37.8	37.8	37.8	37.8
Other direct personnel	0.0	0.0	2.5	2.5	2.5	2.5	2.5
Total direct personnel	0.3	0.3	40.5	40.3	40.3	40.3	40.3
Office of Policy							
Technical personnel	1.0	1.0	0.9	0.8	0.8	0.8	0.8
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	1.0	1.0	0.9	0.8	0.8	0.8	0.8
Office of Chief Financial Officer							
Technical personnel	0.8	0.8	0.0	0.0	0.0	0.0	0.0
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	0.8	0.8	0.0	0.0	0.0	0.0	0.0
Office of Worker and Community Transition							
Technical personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Federal Energy Regulatory Commission							
Technical personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Environmental Management (Bechtel Jacobs Company LLC)							
Technical personnel	138.2	119.6	107.6	108.0	108.0	108.0	108.0
Other direct personnel	14.7	11.3	10.2	9.8	9.8	9.8	9.8
Total direct personnel	152.9	130.9	117.8	117.8	117.8	117.8	117.8
Subtotal DOE Programs							
Technical personnel	1337.3	1657.9	1452.5	1447.1	1447.1	1447.1	1447.1
Other direct personnel	229.5	239.3	225.4	219.7	219.7	219.7	219.7
Total direct personnel	1566.8	1897.1	1677.9	1666.8	1666.8	1666.8	1666.8
DOE Contractors and Operations Office							
Technical personnel	225.6	232.7	218.3	215.8	215.8	215.8	215.8
Other direct personnel	24.6	11.7	11.0	8.6	8.6	8.6	8.6
Total direct personnel	250.2	244.4	229.3	224.4	224.4	224.4	224.4
Cooperative R&D Agreements							
Technical personnel	38.6	19.0	12.9	7.9	7.9	7.9	7.9
Other direct personnel	0.0	15.5	16.6	22.6	22.6	22.6	22.6
Total direct personnel	38.6	34.5	29.5	30.5	30.5	30.5	30.5
Total DOE Programs							
Technical personnel	1601.5	1909.6	1683.7	1670.8	1670.8	1670.8	1670.8
Other direct personnel	254.1	266.4	253.0	250.9	250.9	250.9	250.9
Total direct personnel	1855.6	2176.0	1936.7	1921.7	1921.7	1921.7	1921.7

Table 9.4 (continued)

Personnel by assistant secretarial level office by fiscal year

[Full-time equivalent (FTE) employees]

	2000	2001	2002	2003	2004	2005	2006
Work for Others							
Nuclear Regulatory Commission							
Technical personnel	27.2	20.2	18.9	14.0	14.0	14.0	14.0
Other direct personnel	1.3	0.2	0.2	0.2	0.2	0.2	0.2
Total direct personnel	28.5	20.4	19.1	14.2	14.2	14.2	14.2
Department of Defense							
Technical personnel	127.3	66.8	66.4	63.3	63.3	63.3	63.3
Other direct personnel	23.4	35.6	38.2	38.2	38.2	38.2	38.2
Total direct personnel	150.7	102.4	104.6	101.5	101.5	101.5	101.5
National Aeronautics and Space Administration							
Technical personnel	14.7	7.9	12.7	11.4	11.4	11.4	11.4
Other direct personnel	4.9	3.3	5.3	6.0	6.0	6.0	6.0
Total direct personnel	19.6	11.3	18.0	17.4	17.4	17.4	17.4
Department of Health and Human Services							
Technical personnel	24.7	8.2	4.1	2.5	2.5	2.5	2.5
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	24.7	8.2	4.1	2.5	2.5	2.5	2.5
Environmental Protection Agency							
Technical personnel	17.3	19.4	15.2	12.9	12.9	12.9	12.9
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	17.3	19.4	15.2	12.9	12.9	12.9	12.9
National Science Foundation							
Technical personnel	0.2	0.2	0.0	0.0	0.0	0.0	0.0
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	0.2	0.2	0.0	0.0	0.0	0.0	0.0
Federal Emergency Management Agency							
Technical personnel	3.9	3.9	2.9	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	3.9	3.9	2.9	1.5	1.5	1.5	1.5
Department of Transportation							
Technical personnel	28.4	17.5	23.1	23.1	23.1	23.1	23.1
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	28.4	17.5	23.1	23.1	23.1	23.1	23.1
Other Federal agencies							
Technical personnel	1.6	1.6	3.5	3.7	3.7	3.7	3.7
Other direct personnel	6.5	14.4	32.0	32.0	32.0	32.0	32.0
Total direct personnel	8.1	16.0	35.5	35.7	35.7	35.7	35.7
Electric Power Research Institute							
Technical personnel	3.0	0.9	1.8	1.8	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	3.0	0.9	1.8	1.8	0.1	0.1	0.1
Other nonfederal agencies							
Technical personnel	58.5	42.9	36.1	26.9	26.9	26.9	26.9
Other direct personnel	9.9	32.1	27.0	28.0	28.0	28.0	28.0
Total direct personnel	68.4	75.0	63.1	54.9	54.9	54.9	54.9

Table 9.4 (continued)

Personnel by assistant secretarial level office by fiscal year

[Full-time equivalent (FTE) employees]

	2000	2001	2002	2003	2004	2005	2006
Total Work for Others							
Technical personnel	306.8	189.5	184.7	161.1	159.4	159.4	159.4
Other direct personnel	46.0	85.6	102.7	104.4	104.4	104.4	104.4
Total direct personnel	352.8	345.9	287.4	265.5	263.8	263.8	263.8
Total ORNL							
Technical personnel	1908.3	2099.1	1868.4	1831.9	1830.2	1830.2	1830.2
Other direct personnel	300.1	352.0	355.7	355.3	355.3	355.3	355.3
Total direct personnel (FTE)	2208.4	2451.1	2224.1	2187.2	2185.5	2185.5	2185.5

Supplemental Information

Laboratory Directed Research and Development

ORNL's plans for Laboratory Directed Research and Development (LDRD) are described in Sect. 5.7 of the Institutional Plan. *ORNL Laboratory Directed Research and Development Program: Annual Report to the Department of Energy Summarizing Fiscal Year 2000* (ORNL/PPA-2001/1, March 2001) provides a program overview, funding summaries, and project summaries for the LDRD Program.

Work for Other Sponsors

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 regulatory actions and decisions. Approximately 25 projects are administered through the Nuclear Technology Programs Office; work is performed by 5 ORNL divisions and 1 BWXT Y-12, LLC, organization. These projects are carried out in agreement with the Memorandum of Understanding established between the Department of Energy (DOE) and NRC in 1978 and revised in 1998, and the work is conducted primarily for the NRC Offices of Nuclear Regulatory Research (RES), Nuclear Material Safety and Safeguards (NMSS), and Nuclear Reactor Regulation (NRR).

Research areas for RES include storage and transport of high-burnup spent fuel, 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, and instrumentation and controls technology. 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.

Another area of emphasis for RES is the collection, review, analysis, and evaluation of plant safety performance data. ORNL supports RES with the resolution of operational performance issues, benchmarking the operating records of power plants for diagnostic assessments, trending events, providing technical assistance, and responding to inquiries from NRC staff on operational and safety-related issues. ORNL operates and maintains the Sequence Coding and Search System (SCSS), the NRC's official database of reportable operational events at commercial nuclear power plants.

New areas of support for RES include assistance with pre-application review activities for modular high-temperature gas-cooled reactors. Activities include the evaluation of experimental data on the high-temperature thermal and mechanical properties of irradiated graphite and modeling and performing pebble bed modular reactor accident simulations. In response to recent national events, ORNL is also providing vulnerability assessments of nuclear facilities certified by the NRC.

Research areas for NMSS include criticality safety, shielding and thermal analyses of nuclear fuel facilities and cask designs, environmental review of licensee facilities, and review of terminated materials handling license files. The ORNL-developed computer code SCALE has been extended for NMSS use as this organization's reference code for criticality safety, shielding, and thermal analyses.

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; and fission product chemistry, iodine evolution, and pH control.

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 and coordination with BWXT Y-12, LLC, and other research partners and include basic and applied research, development, technology demonstration programs, and prototyping.

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 the latest generation of battlefield-portable mass spectrometers for point contact and stand-off detection of chemical and biological agents. New instrumentation, sensors, and data processing technologies are also being developed to improve detection of unexploded ordnance (UXO) and mines from land-, air-, and marine-based systems. This work is conducted in collaboration with DOD, academia, the private sector, and other DOE national laboratories.

Improved diagnostic and prognostic systems support the manufacture, life extension, and maintenance of weapon systems. Novel approaches to mobile communications and cyber security are being developed for the information assurance and protection of national security and business data and information. Joint Virtual Analysis Centers are being developed to collect, explore, and represent the information and knowledge contained in intelligence data sources. Common situational awareness tools are being developed to visualize the battle space for certain special military operations.

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 the next generation of transportation and logistics models for defense customers, including transportation planning and tracking for rapid military response planning and execution for international contingencies. Novel applications of autonomous intelligent software are being developed to characterize, understand, and predict elements of the defense supply chain.

Environmental research is conducted for the Strategic Environmental R&D Program and the Environmental Security Technology Certification Program. These programs support the research, development, demonstration, validation, and evaluation of technology to better manage military base operations and legacy waste (e.g., UXO) 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.

Toxicologists and health professionals at ORNL contribute technical advice, assessments, hearing testimony, and critiques to ensure scientifically supported and health-based exposure criteria for chemical warfare agents. This work has provided the basis for military and civilian chemical warfare agent disposal determinations, military installation restoration programs, and chemical weapons treaty compliance. ORNL staff also develop and implement independent assessments of programs to ensure, monitor, and evaluate the quality of data used by DOD for making decisions in environmental remediation and risk assessment programs.

U.S. Department of Transportation

ORNL assists the Department of Transportation's 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. This work is part of a broad transportation R&D and technology program (see Sect. 5.6.2.4).

National Aeronautics and Space Administration

ORNL serves as NASA's Distributed Active Archive Center (DAAC) for Biogeochemical Dynamics for the Earth Observing System Data and Information System (EOSDIS). EOSDIS is part of NASA's contribution to the U.S. Global Change Research Program's effort to develop a predictive understanding of the global environment. Data from NASA and other sources archived at the ORNL DAAC are used to calibrate and verify remote sensing data and to parameterize and validate models of local, regional, and global-scale processes for projecting changes in the Earth's ecosystems. ORNL's Walker Branch Watershed on the Oak Ridge Reservation is one of the 24 core land validation sites selected to represent biomes globally. NASA selected the ORNL site because of the long history of these measurements coupled with extensive remote sensing data for the Oak Ridge Reservation. The ORNL DAAC is also working closely with DOE's Carbon Dioxide Information Analysis Center to archive and distribute data from measurement towers throughout the world. In order to promote the sharing of data and information, ORNL developed a modern Web-based system, Mercury ⟨http://mercury.ornl.gov⟩, which assists investigators in documenting data and making them available to users throughout the world, regardless of discipline. The ORNL DAAC uses Mercury for field activities in South America, for validating remote sensing products, and for making available a variety of earth sciences data from NASA-funded centers across North America. ORNL is also supplying NASA with radio-frequency technology and expertise in high-temperature superconductors for an advanced rocket engine; supporting NASA programs in aviation safety; assisting in data compilation on the growth of vegetation; and providing data and information support to a large NASA field campaign to study the tropical forest ecosystem in the Amazon River basin.

U.S. Environmental Protection Agency

ORNL's work for the EPA addresses numerous health and environmental problems and issues. Activities include evaluation of the cost-effectiveness of reducing nitrogen oxide emissions as a means of ozone control; involvement with EPA air quality research and modeling programs through the NARSTO Quality Systems Science Center [a Carbon Dioxide Information Analysis Center (CDIAC) program; see Sect. 5.1.2.2]; activities in quality assurance and archiving of atmospheric chemistry and particulate matter data; support for ecological risk activities; guidance on indicators of landscape pattern and regional vulnerability studies of the biogeochemical cycling of mercury; collaboration with EPA scientists on the Design for the Environment Program; research on decentralized wastewater management concepts; 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; field validation of analysis methods under the Environmental Technology Verification Program; and development of reference dose and reportable quantity profiles to reduce uncertainty in risk assessments. For the Office of Pesticide Programs, critical evaluations of health, chemistry, and ecological data are performed in support of the registration and reregistration of pesticides. For the Office of Pollution Prevention and Toxics, Acute Exposure Guideline Levels are derived to provide guidance to emergency planners in the event of accidental releases of chemicals, and assistance is provided to the High Production Chemical Volume Program, which is part of an international effort to better characterize the potential hazards of these chemicals.

U.S. Department of Health and Human Services

The U.S. Department of Health and Human Services supports research in protein crystallography, bioanalytical chemistry, genetics, functional genomics, and toxicology through various institutes of the National Institutes of Health. Research into the genetics of obesity is supported through a grant from the National Institute for Diabetes and Digestive and Kidney Diseases. Investigations of the genetics of germ cell susceptibility to environmental mutagenesis are supported by an interagency agreement with the National Institute of Environmental Health Sciences. ORNL also conducts research for the National Heart, Lung, and Blood Institute; the National Institute on Aging; the National Institute Human Genome Research Institute; the National Institute for Mental Health; and the National Institute of General Medicine. Genetic, reproductive, and general toxicology databases are developed, analyzed, and evaluated for the Food and Drug Administration (FDA), the National Library of Medicine, and the National Toxicology Program, with support from the Environmental Protection Agency (EPA). ORNL staff also provide the FDA Center for Food Safety and Applied Nutrition with critical evaluations of toxicology data for food additives.

A National AIDS/Cancer Match Registry developed at ORNL has been used throughout the world to identify tumor types developed in immunocompromised individuals. The project is being repeated to determine the efficacy of AIDS-related drugs and to gain further insights in tumorigenesis.

The NIH National Cancer Institute has published the *Atlas of Cancer Mortality for the United States, 1950–1994*. The atlas shows the geographic patterns of cancer, opening the door for spatial analyses and research on cancer epidemiology and etiology. Establishing correlative spatial and temporal links between cancer incidence and mortality patterns is a critical task in establishing cancer etiology and enhancing cancer prevention. Research at ORNL will focus on developing spatial statistical methods and using geographical information systems to determine correlation among cancer types and a series of social, economic, and environmental factors at various spatial scales.

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 that include engineering assistance, analysis and assessment, and emergency evacuation procedures.

National Science Foundation

The National Science Foundation (NSF) supports studies of nitrogen uptake, cycling, and retention in stream ecosystems using ^{15}N tracer addition experiments. The results will contribute to a better understanding of the mechanism responsible for and controls on ammonium and nitrate uptake and cycling and the effects of increased nitrogen inputs to streams. The NSF also supports 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.

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 Education, 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.
- Projects for the Department of Education include the development of a learning module to teach elementary physical principles as they apply to the construction and testing of a straw-bale wall and the design and programming of an automated decision-making software package for assessing data on secondary education schools and institutions.

- ORNL is collaborating with the U.S. Department of Agriculture (USDA) Office of Energy Policy and New Uses to incorporate data on potential energy crops into models of the agricultural sector used by USDA for economic and policy analyses. This work focuses on the FOLYSYS model developed and maintained for USDA by the University of Tennessee.
- ORNL serves the U.S. Agency for International Development as a center of expertise on energy planning, policy development, and renewable energy applications. Activities include research; analysis; technical assistance; project development, implementation, and evaluation; and information dissemination.
- ORNL scientists conduct environmental research in the Great Smoky Mountains National Park for the National Park Service.
- Support is provided to the Bureau of Labor Statistics in artificial intelligence systems to provide estimates of consumer prices index and survey automation.
- ORNL provides support in environmental management of water resources to several federal agencies. For example, ORNL staff serve as technical advisors to the U.S. Army Corps of Engineers on environmental issues such as hydropower impacts on fish and wildlife and instream flow policies and to the Northwest Power Planning Council and the Office of Science and Technology Policy on restoration of Pacific salmon.
- Under the sponsorship of the interagency Strategic Environmental R&D Program/Environmental Security Technology Certification Program, ORNL staff are involved in an interagency group including DOE, DOD, 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. Ecological models developed at ORNL are used to address land management issues.
- The U.S. Geological Survey supports the development of regional and national data management and analysis tools as part of the National Biological Information Infrastructure program.

Nonfederal Organizations

ORNL performs research for and in collaboration with many nonfederal entities, both public and private. 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 evaluation of the ecological affects associated with water use for power generation; a project co-funded by DOE and EPRI to develop and demonstrate intelligent control systems for nuclear power plants; 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; and physical chemistry studies related to power-plant steam cycles, which draw on fundamental work supported by the Office of Basic Energy Sciences in DOE's Office of Science. Associated with EPRI research is work funded by Babcock and Wilcox (B&W) to develop a control algorithm that will be implemented by the B&W Owners Group on new digital control hardware.

Other Nonfederal Organizations

Private industry interacts with ORNL through cooperative R&D agreements, user agreements, licensing agreements, and other mechanisms. For example, ORNL supports the Idaho Power Company with environmental studies of how hydroelectric projects affect fish populations, an activity that complements other work for DOE's Hydropower Program. 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. States make use of ORNL expertise through agreements

such as those with the State of Florida to study the environmental behavior of mercury; through the State Partnerships Program; and through user facility agreements, cooperative R&D agreements, and other mechanisms.

Supplemental Tables

Table S.1 presents projected resources (funding and direct personnel) by program. The projections in Table S.1 are based on funding requested in the FY 2002 budget submission documents, with some adjustments for subsequent guidance. The projections include some funding for construction that supports the major laboratory initiatives proposed in Sect. 4 of the Institutional Plan.

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

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

Table S.6 provides details on the use of ORNL's designated user facilities during FY 2000. Table S.7 provides details on participation in ORNL's university and science education programs. Table S.8 provides projected estimates of Laboratory Directed Research and Development (LDRD) funding.

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

	2000	2001	2002	2003	2004	2005	2006
Undersecretary for Energy, Science, and Environment							
Office of Science							
Magnetic Fusion—AT							
Total operating	18.2	16.7	17.6	22.0	23.6	23.9	24.0
Capital equipment	0.4	0.3	0.2	0.2	0.2	0.2	0.2
Total program	18.6	17.0	17.8	22.2	23.8	24.1	24.2
Total direct personnel (FTE)	70.8	64.9	68.5	58.6	58.6	58.6	58.6
High Energy Physics—KA							
Total operating	0.5	0.8	0.6	0.7	0.7	0.7	0.7
Capital equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total program	0.5	0.8	0.6	0.7	0.7	0.7	0.7
Total direct personnel (FTE)	2.3	1.3	1.0	1.0	1.0	1.0	1.0
Nuclear Physics—KB							
Total operating	14.1	14.0	12.9	14.3	14.6	15.1	15.4
Capital equipment	1.7	1.4	1.2	1.4	1.4	1.4	1.4
Construction	0.4	0.4	0.4	0.4	0.9	2.9	3.4
Total program	16.2	15.8	14.5	16.1	16.9	19.4	20.2
Total direct personnel (FTE)	62.8	64.4	65.3	65.3	65.3	65.3	65.3
Basic Energy Sciences—KC							
Operating expense (excluding SNS)	80.1	82.9	81.0	81.8	83.0	84.3	84.8
Operating expense, SNS	17.7	19.0	15.0	14.4	18.4	33.1	33.8
Total operating	97.8	101.9	96.0	96.2	101.4	117.4	118.6
Capital equipment (excluding SNS)	6.8	4.2	1.5	5.0	5.0	5.0	5.0
Capital equipment, GPE[a] Landlord	3.3	1.9	1.4	4.0	5.0	5.0	5.0
Capital equipment, SNS	0.2	0.1	0.1	0.0	0.0	0.0	0.0
Construction (excluding SNS)	2.4	1.6	5.0	1.1	1.1	1.1	1.1
Construction, GPP[b] Landlord	4.4	5.8	6.4	12.0	15.0	15.0	15.0
Construction, SNS	100.0	258.9	218.2	210.6	124.6	79.8	41.1
Proposed construction	0.0	0.0	0.0	11.0	27.0	15.1	0.0
Total program	214.9	374.4	328.6	339.9	279.9	238.4	185.8
Total direct personnel (FTE)	419.7	459.9	434.0	444.4	444.4	444.4	444.4
Energy Research Analyses—KD							
Total operating	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel (FTE)	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Multiprogram Energy Laboratory—Facility Support—KG							
Total operating	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction, MGPF	1.1	6.6	7.6	13.8	6.6	0.0	0.0
Proposed construction	0.0	0.0	0.0	2.6	23.3	21.4	32.9
Total program	1.1	6.6	7.6	16.4	29.9	21.4	32.9
Total direct personnel (FTE)	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Computational and Technology Research—KJ							
Total operating	12.3	22.2	21.2	23.5	25.5	27.5	29.5
Capital equipment	0.1	0.3	0.4	0.4	0.5	0.5	0.5
Total program	12.4	22.5	21.6	23.9	26.0	28.0	30.0
Total direct personnel (FTE)	53.0	52.4	50.0	50.6	50.6	50.6	50.6

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

	2000	2001	2002	2003	2004	2005	2006
Biological and Environmental Research—KP							
Total operating	29.2	39.4	31.9	34.1	33.7	34.7	35.3
Capital equipment	2.5	3.9	1.6	1.2	0.7	0.8	0.8
Construction	0.0	2.5	10.0	1.4	0.0	0.0	0.0
Total program	31.7	45.8	43.5	36.7	34.4	35.5	36.1
Total direct personnel (FTE)	99.7	153.3	124.1	117.6	117.6	117.6	117.6
Office of Science Program Direction—KX							
Total operating	0.9	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel (FTE)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Office of Science							
Operating expense	173.1	195.0	180.2	190.8	199.5	219.3	223.5
Capital equipment	11.5	10.1	4.9	8.2	7.8	7.9	7.9
Capital equipment, GPE Landlord	3.3	1.9	1.4	4.0	5.0	5.0	5.0
Capital equipment, SNS	0.2	0.1	0.1	0.0	0.0	0.0	0.0
Construction (excluding SNS)	3.9	11.1	23.0	16.7	8.6	4.0	4.5
Construction, GPP Landlord	4.4	5.8	6.4	12.0	15.0	15.0	15.0
SNS construction	100.0	258.9	218.2	210.6	124.6	79.8	41.1
Proposed construction	0.0	0.0	0.0	13.6	50.3	36.5	32.9
Total program	296.4	482.9	434.2	455.9	410.8	367.5	329.9
Total direct personnel (FTE)	708.6	801.8	742.2	737.7	737.7	737.7	737.7
Office of Energy Efficiency and Renewable Energy							
Solar and Renewable Resource Technologies—EB							
Total operating	19.6	24.2	26.0	24.1	24.1	24.1	24.1
Capital equipment	0.3	1.4	0.9	0.1	0.1	0.1	0.1
Total program	19.9	25.6	26.9	24.2	24.2	24.2	24.2
Total direct personnel (FTE)	86.0	98.5	105.8	104.0	104.0	104.0	104.0
Buildings Sector—EC							
Total operating	19.3	19.7	24.3	20.5	20.5	20.5	20.5
Capital equipment	0.5	1.8	0.4	0.2	0.2	0.2	0.2
Total program	19.8	21.5	24.7	20.7	20.7	20.7	20.7
Total direct personnel (FTE)	10.7	7.1	8.8	7.0	7.0	7.0	7.0
Industrial Sector—ED							
Total operating	28.3	24.8	30.4	24.7	24.7	24.7	24.7
Capital equipment	0.4	0.6	0.1	0.0	0.0	0.0	0.0
Proposed construction	0.0	0.0	0.0	12.0	0.0	0.0	0.0
Total program	28.7	25.4	30.5	36.7	24.7	24.7	24.7
Total direct personnel (FTE)	92.2	68.2	83.5	66.7	66.7	66.7	66.7
Transportation Sector—EE							
Total operating	39.6	45.0	37.8	40.8	40.8	40.8	40.8
Capital equipment	3.9	1.4	0.8	0.3	0.3	0.3	0.3
Total program	43.5	46.4	38.6	41.1	41.1	41.1	41.1
Total direct personnel (FTE)	129.5	162.4	136.4	140.1	140.1	140.1	140.1
Policy and Management—EH							
Total operating	0.9	0.8	0.8	0.8	0.8	0.8	0.8
Total direct personnel (FTE)	2.1	1.9	1.9	1.9	1.9	1.9	1.9
Utility Sector—EK							
Total operating	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel (FTE)	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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

	2000	2001	2002	2003	2004	2005	2006
Federal Energy Management Program—EL							
Total operating	2.6	4.1	5.6	4.1	4.1	4.1	4.1
Total direct personnel (FTE)	7.5	7.3	10.0	7.3	7.3	7.3	7.3
In-House Energy Management—WB							
Total operating	(0.2)	0.0	(0.1)	0.0	0.0	0.0	0.0
Total direct personnel (FTE)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Office of Energy Efficiency and Renewable Energy							
Operating expense	110.1	118.6	124.8	115.0	115.0	115.0	115.0
Capital equipment	5.1	5.2	2.2	0.6	0.6	0.6	0.6
Proposed construction	0.0	0.0	0.0	12.0	0.0	0.0	0.0
Total program	115.2	123.8	127.0	127.6	115.6	115.6	115.6
Total direct personnel (FTE)	328.1	345.4	346.4	327.0	327.0	327.0	327.0
Office of Nuclear Energy, Science, and Technology							
Nuclear Energy R&D—AF							
Total operating	5.2	6.9	6.1	8.0	11.1	15.8	17.5
Capital equipment	(0.1)	0.1	0.1	0.1	0.1	0.1	0.1
Construction	0.0	0.0	3.0	0.1	0.0	0.0	0.0
Total program	5.1	7.0	9.2	8.2	11.2	15.9	17.6
Total direct personnel (FTE)	16.1	26.1	23.1	28.2	28.2	28.2	28.2
Naval Reactors—AJ							
Total operating	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total direct personnel (FTE)	0.3	0.2	0.2	0.2	0.2	0.2	0.2
Nuclear Fuel Cycle Security—AP							
Total operating	0.0	0.0	2.0	20.0	35.0	40.0	22.0
Total direct personnel (FTE)	11.6	11.6	42.8	53.8	53.8	53.8	53.8
Uranium Enrichment—CD							
Total operating	1.5	0.2	(0.1)	0.0	0.0	0.0	0.0
Total direct personnel (FTE)	3.0	3.0	0.0	0.0	0.0	0.0	0.0
Policy and Management—KK							
Total operating	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel (FTE)	0.7	0.7	0.1	0.1	0.1	0.1	0.1
Isotope Production and Distribution Program—ST							
Total operating	10.8	11.8	11.4	12.0	12.0	12.0	12.0
Capital equipment	(0.2)	0.0	0.0	0.0	0.0	0.0	0.0
Total program	10.6	11.8	11.4	12.0	12.0	12.0	12.0
Total direct personnel (FTE)	30.6	33.2	32.1	31.9	31.9	31.9	31.9
Total Office of Nuclear Energy, Science and Technology							
Operating expense	17.7	19.0	19.5	40.1	58.2	67.9	51.6
Capital equipment	(0.3)	0.1	0.1	0.1	0.1	0.1	0.1
Construction	0.0	0.0	3.0	0.1	0.0	0.0	0.0
Total program	17.4	19.1	22.6	40.3	58.3	68.0	51.7
Total direct personnel (FTE)	62.3	74.9	98.3	114.2	114.2	114.2	114.2
Office of Fossil Energy							
Coal—AA							
Total operating	5.2	9.7	2.8	5.1	5.3	5.3	5.3
Total direct personnel (FTE)	25.3	113.3	32.7	30.1	30.1	30.1	30.1
Gas—AB							
Total operating	3.2	(1.3)	4.2	2.9	2.9	2.9	2.9
Total direct personnel (FTE)	21.2	0.0	8.0	3.0	3.0	3.0	3.0

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

	2000	2001	2002	2003	2004	2005	2006
Petroleum—AC							
Total operating	2.6	9.7	2.8	5.1	5.3	5.2	5.2
Total direct personnel (FTE)	11.8	17.0	13.6	10.6	10.6	10.6	10.6
Fossil Energy Environmental Restoration—AW							
Total operating	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel (FTE)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Innovative Clean Coal Technology—AZ							
Total operating	0.3	0.3	0.1	0.2	0.2	0.2	0.2
Total direct personnel (FTE)	0.9	2.4	0.8	0.0	0.0	0.0	0.0
Strategic Petroleum Reserve—SA							
Total operating	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total direct personnel (FTE)	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Total Office of Fossil Energy							
Total operating	11.4	12.3	10.0	11.4	11.8	11.7	11.7
Total direct personnel (FTE)	59.8	133.3	55.7	44.3	44.3	44.3	44.3
Energy Information Administration							
National Energy Information System—TA							
Total operating	0.0	0.1	(0.1)	0.0	0.0	0.0	0.0
Total direct personnel (FTE)	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Total Energy Information Administration							
Total operating	0.0	0.1	(0.1)	0.0	0.0	0.0	0.0
Total direct personnel (FTE)	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Office of Environmental Management							
Environmental Management—EM (ORNL Financial Plan)							
Total operating	25.1	32.2	28.7	29.2	28.7	28.7	28.7
Capital equipment	(0.2)	0.2	0.2	0.2	0.2	0.2	0.2
Total program	24.9	32.4	28.9	29.4	28.9	28.9	28.9
Total direct personnel (FTE)	103.9	111.0	98.9	98.6	98.6	98.6	98.6
Total Office of Environmental Management							
Total operating	25.1	32.2	28.7	29.2	28.7	28.7	28.7
Capital equipment	(0.2)	0.2	0.2	0.2	0.2	0.2	0.2
Total program	24.9	32.4	28.9	29.4	28.9	28.9	28.9
Total direct personnel (FTE)	103.9	111.0	98.9	98.6	98.6	98.6	98.6
Office of Civilian Radioactive Waste Management							
Nuclear Waste Fund—DF							
Total operating	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel (FTE)	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Total Office of Civilian Radioactive Waste Management							
Total operating	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel (FTE)	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Undersecretary for National Nuclear Security							
Office of the Deputy Administrator for Defense Programs							
Weapons Activities—DP							
Total operating	18.6	18.7	21.1	22.9	23.6	24.3	25.1
Capital equipment	(0.1)	0.0	3.3	3.0	3.0	3.0	3.0
Proposed construction	0.0	0.0	0.0	0.7	0.0	0.0	0.0
Total program	18.5	18.7	24.4	26.6	26.6	27.3	28.1
Total direct personnel (FTE)	93.6	79.8	90.0	103.6	103.6	103.6	103.6

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

	2000	2001	2002	2003	2004	2005	2006
Total Deputy Administrator for Defense Programs							
Total operating	18.6	18.7	21.1	22.9	23.6	24.3	25.1
Capital equipment	(0.1)	0.0	3.3	3.0	3.0	3.0	3.0
Construction	0.0	0.0	0.0	0.7	0.0	0.0	0.0
Total program	18.5	18.7	24.4	26.6	26.6	27.3	28.1
Total direct personnel (FTE)	93.6	79.8	90.0	103.6	103.6	103.6	103.6
Deputy Administrator for Defense Nuclear Nonproliferation							
Fissile Materials Disposition—GA							
Total operating	10.6	24.4	8.3	12.5	11.0	12.0	11.0
Total direct personnel (FTE)	19.4	199.0	67.7	64.6	64.6	64.6	64.6
Nuclear Safeguards and Security—GD							
Total operating	0.1	1.2	(0.3)	0.0	0.0	0.0	0.0
Capital equipment	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Total program	0.1	1.3	(0.3)	0.0	0.0	0.0	0.0
Total direct personnel (FTE)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Arms Control and Nonproliferation—GJ							
Total operating	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel (FTE)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Deputy Administrator for Defense Nuclear Nonproliferation							
Total operating	10.7	25.6	8.0	12.5	11.0	12.0	11.0
Capital equipment	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Total program	10.7	25.7	8.0	12.5	11.0	12.0	11.0
Total direct personnel (FTE)	19.5	199.0	67.7	64.6	64.6	64.6	64.6
Departmental Staff and Support Offices							
Office of Environment, Safety and Health							
Environment, Safety, and Health (Non-Defense)—HC							
Total operating	1.8	1.3	1.2	1.2	1.2	1.3	1.2
Total direct personnel (FTE)	22.3	8.1	7.5	7.1	7.1	7.1	7.1
Environment, Safety, and Health (Defense)—HD							
Total operating	0.4	0.7	0.9	0.3	0.2	0.2	0.2
Total direct personnel (FTE)	1.8	1.6	2.1	0.7	0.7	0.7	0.7
Total Office of Environment, Safety and Health							
Total operating	2.2	2.0	2.1	1.5	1.4	1.5	1.4
Total direct personnel (FTE)	24.0	9.8	9.6	7.8	7.8	7.8	7.8
Office of Counterintelligence							
Counterintelligence—CN							
Total operating	1.8	1.3	1.4	1.4	1.4	1.4	1.4
Total direct personnel (FTE)	11.7	9.2	9.9	10.1	10.1	10.1	10.1
Total Office of Counterintelligence							
Total operating	1.8	1.3	1.4	1.4	1.4	1.4	1.4
Total direct personnel (FTE)	11.7	9.2	9.9	10.1	10.1	10.1	10.1
Office of Security and Emergency Operations							
Security and Emergency Operations—SO							
Total operating	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel (FTE)	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Field Security—FS							
Total operating	0.0	2.9	6.7	8.1	8.4	8.7	9.0
Total direct personnel (FTE)	0.0	0.0	40.2	40.0	40.0	40.0	40.0

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

	2000	2001	2002	2003	2004	2005	2006
Total Office of Security and Emergency Operations							
Total operating	0.1	2.9	6.7	8.1	8.4	8.7	9.0
Total direct personnel (FTE)	0.3	0.0	40.5	40.3	40.3	40.3	40.3
Office of Policy							
Emergency Planning—NC							
Total operating	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel (FTE)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Policy, Analysis, and Systems Studies—PE							
Total operating	(0.1)	0.1	0.0	0.0	0.0	0.0	0.0
Total direct personnel (FTE)	1.0	1.0	0.9	0.8	0.8	0.8	0.8
Total Office of Policy							
Total operating	(0.1)	0.1	0.0	0.0	0.0	0.0	0.0
Total direct personnel (FTE)	1.0	1.0	0.9	0.8	0.8	0.8	0.8
Office of Chief Financial Officer							
Pollution Prevention—86							
Total operating	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel (FTE)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oak Ridge Landlord—AH (Museum)							
Total operating	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel (FTE)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Administration Program Direction—WA							
Total operating	0.2	0.0	0.1	0.0	0.0	0.0	0.0
Total direct personnel (FTE)	0.8	0.8	0.0	0.0	0.0	0.0	0.0
Total Office of Chief Financial Officer							
Total operating	0.6	0.0	0.1	0.0	0.0	0.0	0.0
Total direct personnel (FTE)	0.8	0.8	0.0	0.0	0.0	0.0	0.0
Office of Worker and Community Transition							
Worker and Community Transition Program—GG							
Total operating	3.4	2.2	(0.4)	0.0	0.0	0.0	0.0
Total direct personnel (FTE)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Office of Worker and Community Transition							
Total operating	3.4	2.2	(0.4)	0.0	0.0	0.0	0.0
Total direct personnel (FTE)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Federal Energy Regulatory Commission							
Federal Energy Regulatory Commission—VR							
Total operating	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel (FTE)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Federal Energy Regulatory Commission							
Total operating	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel (FTE)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Office of International Affairs							
International Policy Studies—IA							
Total operating	0.0	0.2	0.1	0.2	0.2	0.2	0.2
Total direct personnel (FTE)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Office of International Affairs							
Total operating	0.0	0.2	0.1	0.2	0.2	0.2	0.2
Total direct personnel (FTE)	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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

	2000	2001	2002	2003	2004	2005	2006
Environmental Management (Bechtel Jacobs Company LLC)							
Total operating	26.1	20.0	18.0	18.0	18.0	18.0	18.0
Total direct personnel (FTE)	152.9	130.9	117.8	117.8	117.8	117.8	117.8
Subtotal DOE Programs							
Total operating	400.9	450.3	420.2	451.1	477.2	508.7	496.6
Capital equipment (excluding SNS)	16.0	15.7	10.7	12.1	11.7	11.8	11.8
Capital equipment, SNS	0.2	0.1	0.1	0.0	0.0	0.0	0.0
Capital equipment, GPE Landlord	3.3	1.9	1.4	4.0	5.0	5.0	5.0
Construction (excluding SNS)	3.9	11.1	26.0	16.8	8.6	4.0	4.5
Construction, GPP Landlord	4.4	5.8	6.4	12.0	15.0	15.0	15.0
SNS construction	100.0	258.9	218.2	210.6	124.6	79.8	41.1
Proposed construction	0.0	0.0	0.0	26.3	50.3	36.5	32.9
Total	528.7	743.8	683.0	732.9	692.4	660.8	606.9
Total direct personnel (FTE)	1566.8	1897.1	1677.9	1666.8	1666.8	1666.8	1666.8
DOE Contractors and Operations Offices							
Total operating	53.5	51.7	48.5	48.5	40.0	40.0	40.0
Total direct personnel (FTE)	250.2	244.4	229.3	224.4	224.4	224.4	224.4
Cooperative R&D Agreements							
Total operating	7.0	9.0	6.1	6.1	6.1	6.1	6.1
Total direct personnel (FTE)	38.6	34.5	29.5	30.5	30.5	30.5	30.5
Total DOE Programs							
Total operating	461.4	511.0	474.8	505.7	523.3	554.8	542.7
Capital equipment (excluding SNS)	16.0	15.7	10.7	12.1	11.7	11.8	11.8
Capital equipment, GPE Landlord	3.3	1.9	1.4	4.0	5.0	5.0	5.0
Capital equipment, SNS	0.2	0.1	0.1	0.0	0.0	0.0	0.0
Construction (excluding SNS)	3.9	11.1	26.0	16.8	8.6	4.0	4.5
Construction, GPP Landlord	4.4	5.8	6.4	12.0	15.0	15.0	15.0
SNS construction	100.0	258.9	218.2	210.6	124.6	79.8	41.1
Proposed construction	0.0	0.0	0.0	26.3	50.3	36.5	32.9
Total	589.2	804.5	737.6	787.5	738.5	706.9	653.0
Total direct personnel (FTE)	1855.8	2176.0	1936.7	1921.7	1921.7	1921.7	1921.7
Work for Others							
Nuclear Regulatory Commission							
Operating expense	8.1	7.8	7.3	6.8	6.5	6.5	6.5
Total direct personnel (FTE)	28.5	20.4	19.1	14.2	14.2	14.2	14.2
Department of Defense							
Operating expense	33.5	31.4	31.2	31.3	20.4	20.6	19.0
Total direct personnel (FTE)	150.7	102.4	104.6	101.5	101.5	101.5	101.5
National Aeronautics and Space Administration							
Operating expense	4.8	4.0	6.4	6.6	3.6	3.6	3.6
Total direct personnel (FTE)	19.7	11.3	18.0	17.4	17.4	17.4	17.4
Department of Health and Human Services							
Operating expense	2.1	1.6	0.8	1.0	1.0	0.8	0.8
Total direct personnel (FTE)	24.7	8.2	4.1	2.5	2.5	2.5	2.5
Environmental Protection Agency							
Operating expense	4.2	5.1	4.0	3.9	3.1	3.2	3.4
Total direct personnel (FTE)	17.3	19.4	15.2	12.9	12.9	12.9	12.9

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

	2000	2001	2002	2003	2004	2005	2006
National Science Foundation							
Operating expense	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel (FTE)	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Federal Emergency Management Agency							
Operating expense	0.4	0.8	0.8	0.8	0.8	0.8	0.8
Total direct personnel (FTE)	3.9	3.9	2.9	1.5	1.5	1.5	1.5
Department of Transportation							
Operating expense	7.1	5.6	7.4	7.4	4.6	4.6	4.6
Total direct personnel (FTE)	28.4	17.5	23.1	23.1	23.1	23.1	23.1
Other Federal agencies							
Operating expenses	4.9	3.2	7.1	7.2	25.0	24.9	26.3
Total direct personnel (FTE)	8.1	16.0	35.5	35.7	35.7	35.7	35.7
Electric Power Research Institute							
Operating expense	1.0	0.7	1.4	1.4	0.1	0.1	0.1
Total direct personnel (FTE)	3.0	0.9	1.8	1.8	0.1	0.1	0.1
Other nonfederal agencies							
Operating expense	14.0	24.5	20.6	22.4	14.7	14.7	14.7
Total direct personnel (FTE)	68.4	75.0	63.1	54.9	54.9	54.9	54.9
Total Work for Others							
Operating expense	80.1	84.7	87.0	88.8	79.8	79.8	79.8
Total direct personnel (FTE)	352.8	275.0	287.4	265.5	263.8	263.8	263.8
Total Program Resources							
Operating expense	541.5	595.7	561.8	594.5	603.1	634.6	622.5
Capital equipment (excluding SNS)	16.0	15.7	10.7	12.1	11.7	11.8	11.8
Capital equipment, SNS	0.2	0.1	0.1	0.0	0.0	0.0	0.0
Capital equipment, GPE Landlord	3.3	1.9	1.4	4.0	5.0	5.0	5.0
Construction (excluding SNS)	3.9	11.1	26.0	16.8	8.6	4.0	4.5
Construction, GPP Landlord	4.4	5.8	6.4	12.0	15.0	15.0	15.0
SNS construction	100.0	258.9	218.2	210.6	124.6	79.8	41.1
Proposed construction	0.0	0.0	0.0	26.3	50.3	36.5	32.9
Total	669.3	889.2	824.6	876.3	818.3	786.7	732.8
Total direct personnel (FTE)	2208.4	2451.2	2224.1	2187.2	2185.5	2185.5	2185.5

[a]GPE = General Plant Equipment.
[b]GPP = General Plant Project.

Table S.2
Equal Employment Opportunity statistics for 2000

Occupational code	Total (%)[a]		Minority total (%)		White (%)		Black (%)		Hispanic (%)		Native American/ Alaska Native (%)		Asian/Pacific Islander (%)	
	M[b]	F[c]	M	F	M	F	M	F	M	F	M	F	M	F
Officials and managers[d]	350 (83.7)	68 (16.3)	23 (5.5)	7 (1.7)	327 (78.2)	61 (14.6)	20 (4.8)	5 (1.2)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	3 (0.7)	2 (0.5)
Professionals	1518 (78.1)	426 (21.9)	161 (8.3)	50 (2.6)	1357 (69.8)	376 (19.3)	40 (2.1)	23 (1.2)	28 (1.4)	3 (0.2)	2 (0.1)	1 (0.1)	91 (4.7)	23 (1.2)
Technicians	214 (66.5)	108 (33.5)	14 (4.3)	9 (2.8)	200 (62.1)	99 (30.7)	8 (2.5)	7 (2.2)	5 (1.6)	1 (0.3)	0 (0.0)	0 (0.0)	1 (0.3)	1 (0.3)
Office/clerical	14 (2.9)	472 (97.1)	3 (0.6)	59 (12.1)	11 (2.3)	413 (85.0)	3 (0.6)	51 (10.5)	0 (0.0)	2 (0.4)	0 (0.0)	1 (0.2)	0 (0.0)	5 (1.0)
Crafts/ laborers	482 (89.6)	56 (10.4)	54 (10.0)	14 (2.6)	428 (79.6)	42 (7.8)	52 (9.7)	13 (2.4)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.2)	2 (0.4)	0 (0.0)
Service workers	87 (74.4)	30 (25.6)	11 (9.4)	13 (11.1)	76 (65.0)	17 (14.5)	11 (9.0)	10 (8.5)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.9)	0 (0.0)	2 (1.7)
Total	2665 (69.7)	1160 (30.3)	266 (7.0))	152 (4.0)	2399 (62.7)	1008 (26.4)	134 (3.5)	109 (2.8)	33 (0.9)	6 (0.2)	2 (0.1)	4 (0.1)	97 (2.5)	33 (0.9)

[a]Percentage of total number of employees in occupational category.

[b]M = male.

[c]F = female.

[d]As defined on Standard Form 100 (EEO-1), as required by 41 CFR 60-1.7(a).

1.19

0.28

1.19/0.28 = 4.25

white male's chance to be a manager is 4.25 times higher than Asian male

Table S.3
ORNL staff composition (as of December 31, 2000)[a]

	Ph.D.	M.S.	B.S./B.A.	Other	Total
Professional staff					
Scientists	463	148	111	30	752
Engineers	232	222	168	68	690
Management/administrative	100	244	317	259	920
Support staff					
Technicians	0	6	68	249	323
All other	0	4	84	1053	1141
Total ORNL staff	795	624	748	1659	3826

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

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

	2000[a]	2001	2002
Universities			
SNS	0.1	0.0	0.0
ORNL excluding SNS	22.7	25.0	25.0
All others			
SNS	55.7	120.0	125.0
ORNL excluding SNS	135.3	134.0	134.0
Transfers to other DOE facilities			
SNS	0.0	0.0	0.0
ORNL excluding SNS	0.8	1.0	1.0
Total external subcontracts and procurements			
SNS	55.8	120.0	125.0
ORNL excluding SNS	158.8	160.0	160.0

[a]Actual.

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

	2000[a]	2001
Total small and disadvantaged business procurement, in millions of dollars		
SNS	6.2	48.0
ORNL excluding SNS	63.3	73.6
Small and disadvantaged business procurement, as a percentage of total procurement		
SNS	11.0	40.0
ORNL excluding SNS	39.9	46.0

[a]Actual.

Table S.6

Experimenters at ORNL's designated user facilities in FY 2000[a]

	Number of experimenters	Non-ORNL organizations
Bioprocessing Research and Development Center		
ORNL	4	—
Other U.S. government laboratories	0	0
U.S. universities	3	3
U.S. industry	5	3
International organizations	0	0
Total	**12**	**6**
Buildings Technology Center		
ORNL	0	—
Other U.S. government laboratories	0	0
U.S. universities	0	0
U.S. industry	120	28
International organizations	12	2
Total	**132**	**30**
Californium User Facility for Neutron Sciences		
ORNL	1	—
Other U.S. government laboratories	1	1
U.S. universities	1	1
U.S. industry	0	0
International organizations	0	0
Total	**3**	**2**
High Flux Isotope Reactor[b]		
ORNL	55	—
Other U.S. government laboratories	10	4
U.S. universities	51	26
U.S. industry	17	5
International organizations	15	15
Total	**148**	**50**
High Temperature Materials Laboratory		
ORNL	9	—
Other U.S. government laboratories	17	7
U.S. universities	116	52
U.S. industry	168	65
International organizations	0	0
Total	**310**	**124**
Holifield Radioactive Ion Beam Facility		
ORNL	25	—
Other U.S. government laboratories	1	1
U.S. universities	37	11
U.S. industry	2	1
International organizations	5	3
Total	**71**	**17**
Metals Processing Laboratory User Facility (MPLUS)		
ORNL	35	—
Other U.S. government laboratories	0	0
U.S. universities	5	4
U.S. industry	34	27
International organizations	0	0
Total	**74**	**31**

Table S.6 (continued)

Experimenters at ORNL's designated user facilities in FY 2000[a]

	Number of experimenters	Non-ORNL organizations
Oak Ridge Electron Linear Accelerator		
ORNL	10	—
Other U.S. government laboratories	11	2
U.S. universities	4	2
U.S. industry	0	0
International organizations	2	2
Total	**27**	**7**
Oak Ridge National Environmental Research Park[c]		
ORNL	33	—
Other U.S. government laboratories	47	29
U.S. universities	134	26
U.S. industry	0	0
International organizations	3	3
State and educational agencies	28	7
Total	**245**	**65**
Shared Research Equipment (SHaRE) Facility		
ORNL	38	—
Other U.S. government laboratories	3	2
U.S. universities	33	22
U.S. industry	0	0
International organizations	4	4
Total	**78**	**28**
Surface Modification and Characterization Research Facility		
ORNL	31	—
Other U.S. government laboratories	2	2
U.S. universities	45	24
U.S. industry	8	6
International organizations	5	5
Total	**91**	**37**

[a]Four designated user facilities are not included: the Mouse Genetics Research Facility and the Physical Properties Research Center, which were not fully operational in FY 2000; the Computational Center for Industrial Innovation, which was inactive in FY 2000; and the Metrology R&D Laboratory, which is used almost exclusively to support the calibration traceability programs carried out for DOE's Oak Ridge Complex (ORNL, the Y-12 National Security Complex, and the East Tennessee Technology Park).

[b]Statistics do not include 131 users who sent samples to ORNL staff (for neutron scattering studies, neutron activation analysis, or materials irradiation) or who purchased radioisotopes.

[c]Totals do not include approximately 8,700 individuals who participated in the Ecological and Physical Sciences Study Center and the High School Honors Program.

Table S.7
University and science education statistics

	FY 2000		
	Total	Minorities	Women
Precollege student programs			
Adventures in Supercomputing	442	94	21
Appalachian Regional Commission Honors Academy	36	7	11
Project SEED/Hispanic SEED	5	1	4
Special Honors Study	26	1	5
SciCops Camp	26	1	5
Science Explorers Camp	29	2	9
Ecological and Physical Sciences Study Center	8,692	555	4,247
Women in Science and Technology	35	*a*	35
EPSCoR	4	4	3
October Science Day Camp	29	0	11
RoboCamp	26	1	4
Precollege teacher programs			
Adventures in Supercomputing	35	2	21
Appalachian Regional Commission Teacher Leadership Institute	18	4	14
NTEP Elementary Science Leadership Institute	6	0	4
Teacher Research Participation	1	0	0
Women in Science and Technology	7	*a*	7
Undergraduate programs			
Energy Research Undergraduate Laboratory Fellowships	110	45	45
Great Lakes Colleges Association/Associated Colleges of the Midwest Science Semester	18	4	7
Professional Internship Program	30	8	11
Community College Initiative	33	10	7
HERE@ORNL	21	7	12
Graduate programs			
Graduate Student Research Participation Program	1	0	1
Professional Internship Programs	13	2	5
HERE@ORNL	6	2	1
Postgraduate programs			
DOE Postdoctoral Programs	114	4	24
Postgraduate Research Training Program	24	2	8
Faculty programs			
Faculty Research Participation	5	2	0
Great Lakes Colleges Association/Associated Colleges of the Midwest	2	0	1
HBCU Faculty Research	2	2	0

[a]Not tracked.

Table S.8
Laboratory Directed R&D funding projections
($ in millions)

FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006
14.569[a]	14.700	14.800	15.410	15.200	16.100	16.200

[a]Actual cost.

Oak Ridge National Laboratory