ORNL/PPA-99/2

Oak Ridge National Laboratory

Institutional Plan

FY 2000–FY 2004

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Oak Ridge National Laboratory Institutional Plan

FY 2000–FY 2004

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Oak Ridge National Laboratory
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Since January 1, 1996, the Oak Ridge National Laboratory (ORNL) has been managed for the U.S. Department of Energy by Lockheed Martin Energy Research Corporation (LMER), a subsidiary of Lockheed Martin Corporation. The Department's management and operation (M&O) contract with LMER expires on March 31, 2000. A new contract with UT-Battelle, LLC, a partnership of the University of Tennessee and Battelle Memorial Institute, will go into effect on April 1, 2000.

The creation of LMER and the establishment of the present cost-plus-fixed-fee M&O contract were undertaken in response to a request from the director of the Department's Office of Energy Research (now the Office of Science), which has the responsibility for management oversight of ORNL, and as part of an ongoing effort by the Department to improve its management of the national laboratories and streamline its contracting practices. Under this contract, ORNL was granted the opportunity to establish a management arrangement that would support the performance of research and development (R&D) in the most cost-effective and efficient manner possible consistent with the environment in which the Laboratory does business.

Much has been done to improve ORNL's ability to deliver the scientific knowledge and technological solutions that are its principal products in a better, faster, and more cost-effective manner. Resources have been secured to support initiatives that will sustain and extend ORNL's distinctive capabilities. Notable accomplishments in science and technology have strengthened the Laboratory's reputation as a primary provider of R&D addressing national priorities. Operational improvements are making it easier to get things done in an environment that treats safety as an integral part of mission execution.

I am confident that the Laboratory will continue to meet the expectations of the Office of Science and the Department of Energy. This confidence is rooted in ORNL's demonstrated ability to meet the expectations of the Department while responding and adapting to changes in its environment.

Progress in 1999

During the past year, we have made notable progress in extending our ability to conduct R&D.

- The Spallation Neutron Source (SNS) project, now in its second year of Congressionally approved line-item funding, continues to demonstrate the Laboratory's flexibility in dealing with changing circumstances that affect schedules and costs. The project director is working aggressively to complete this major construction project, a collaborative effort engaging the expertise of five national laboratories, on time and within budget. The SNS is an essential element of our major initiative in **neutron sciences**, which also includes upgrading the capabilities of the High Flux Isotope Reactor.

- We have developed a strong program in functional genomics that brings together ORNL's mutant mouse stocks, expertise in genetics, and strengths in analytical technologies, bioinformatics, and computational biology to contribute to the exploration of the structure, organization, and function of genetic material. This program now serves as the cornerstone of a major initiative in **complex biological systems**. This initiative will benefit from the Department's plans to make a significant investment in a new Center for Biological Sciences at ORNL, beginning with the construction of a new home for ORNL's mouse colony. The Laboratory for Comparative and Functional Genomics will bring this important resource to our main site and replace an aging and inadequate facility at the Oak Ridge Y-12 Plant.
- Our **terascale computing and simulation science** initiative supports the Department's need for advances in computing and communications that will enable its researchers to solve problems of extraordinary complexity. This initiative involves the continuing development, integration, and application of computational capabilities for the solution of challenging scientific and technical problems.
- Our new initiative on **energy and environmental systems of the future** 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." This emerging effort will apply a systems approach to the closely linked tasks of improving resource efficiency and reducing the environmental impacts of existing energy sources; providing new sources of available and affordable energy; understanding and addressing the environmental costs and benefits of energy production and use; and assessing the technological, environmental, and socioeconomic factors that must be taken into account in the development of realistic pathways to a sustainable energy future.

We have also continued to deliver notable accomplishments in science and technology.

- ORNL researchers have developed the ability to grow crystalline oxides on silicon and fabricated the first prototype crystalline oxide on silicon transistors. This advance eliminates some of the limitations presented by the silicon oxide insulating gates used in today's semiconductor devices and is expected to lead to dramatic improvements in the ability to fabricate smaller device structures.
- A new droplet technique developed at ORNL allows researchers to combine substances that do not usually mix in homogeneous polymer blend microparticles. In addition to the academic significance of this discovery, the finding clears the way for the development of new materials in the form of bulk composites and blends that can be used for coatings, optoelectronic components, magnetic media, ceramics and special materials, micromanufacturing or nanomanufacturing, and bioengineering.
- The world's sharpest electron microscope image of a crystal, recorded at ORNL using the *Z*-contrast scanning transmission electron microscope, resolves the distance between rows of silicon atoms: 0.78 Å. This image has double the resolution of typical transmission electron microscope images.
- Research carried out in collaboration with Clemson and Harvard universities shows that the radioactivity from decay of iron-group elements produced in supernovas can destroy the strong chemical bond that binds together carbon and oxygen produced in the

precursor star through fusion and ejected in its explosion. This discovery casts doubt on the long-held theory that dust formation from ejecta is inhibited because of the strong C-O bond and opens the way for a new direction of study in astrochemistry. The work has many implications for the astrophysics of supernova dust formation and thus for comet, meteorite, and proto-planetary nebula composition and formation.

- ORNL researchers, working with scientists at the Lawrence Livermore National Laboratory and Case Western Reserve University, have cloned a gene in mice that encodes the largest protein described to date and have identified a homologous human gene. Both genes appear to encode a factor involved in the trafficking and degradation pathways for other proteins in the cell. Chemical mutagenesis efforts at ORNL demonstrate that mutations in this gene lead to a variety of abnormalities in neuromuscular function, gametogenesis, and cell development.
- ORNL's highly efficient generator–absorber–heat exchange (GAX) air conditioning units, which emit no greenhouse gases, are being installed in a California housing development.
- In July 1999, ORNL innovations received 8 R&D 100 awards. These awards are presented annually by *R&D Magazine* for the 100 most technologically significant products and processes of the year. One award was shared with industry partners, one with the Oak Ridge Y-12 Plant, and two with the University of Tennessee.
- For the third consecutive year, two ORNL researchers have won Presidential Early Career Awards for Scientists and Engineers.

We have, as several of these examples demonstrate, continued to use partnerships with other Department of Energy laboratories, universities, and industry as a means of leveraging resources, increasing our scientific productivity, and making the Department's resources available to others in the national interest. One of these partnerships is creating a new asset for East Tennessee: in a collaborative effort with the University of Tennessee, the Development Corporation of Knox County, and the Department of Energy, ground has been broken for a $15 million facility to house the National Transportation Research Center.

We have also seen our continuing focus on safe and efficient operations at reasonable cost pay off in new ways. Our work to implement an integrated safety management system has garnered accolades from Department staff. We have also received praise for successfully launching a new enterprise information system that replaces a number of finance, project management, acquisition, and human resources systems and introduces best business practices in these areas.

Our emphasis on being a good neighbor includes working with customers and stakeholders to foster communication and trust. The addition of the American Museum of Science and Energy to ORNL's scope of work has given us new opportunities for communicating the value of the work of the Laboratory, the Office of Science, and the Department of Energy to a wide audience. Science education programs continue to involve students and teachers at all levels in the research activities of the Laboratory. Our community outreach and community service programs provide an additional means for demonstrating our commitment to being a good neighbor and public partner. A recent example is the Gateway Regional Visitors Center on Knoxville's waterfront. ORNL is a partner with the Department of Energy, Lockheed Martin Energy Systems, Inc., the National Park Service, and the Knoxville Convention and Visitors Bureau in this center, which features permanent exhibits on ORNL science and technology and is located at Knoxville's Volunteer Landing.

Looking Ahead

On March 31, 2000, I will step down as the director of ORNL. Until that time, I will work with the Department of Energy and UT-Battelle to ensure a smooth transition in the management and operation of the Laboratory. Throughout the transition, the highest priority will be to carry out the work of the Laboratory in a safe and environmentally sound manner, demonstrating continued progress on ORNL's program milestones and commitments.

Managing the change associated with a new M&O contract is only one of several near-term challenges that the Laboratory faces. Continuing Congressional support for the Spallation Neutron Source is essential to progress in this key project. ORNL must also maintain and enhance its existing facilities and infrastructure to support excellent R&D and attract the best people to carry out this work. Protecting the health and safety of all of our employees, guest scientists and engineers, visitors, and the general public remains ORNL's prime operational imperative and will be supported by integrated safety management.

I am confident that the Laboratory will continue to do excellent work in all of its fields of endeavor. This institutional plan describes how ORNL will support the missions of the Department of Energy during the planning period and beyond.

Alvin W. Trivelpiece
Director, Oak Ridge National Laboratory
President, Lockheed Martin Energy Research Corporation

2 • Mission, Roles, and Capabilities

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, and ecological research. 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 Lockheed Martin Energy Research Corporation.

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 and technology, energy resources, environmental quality, and national 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 security.

2.3 • Operational Imperatives

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

- Plan and conduct all operations with due regard for the health and safety of all employees, guest scientists and engineers, visitors, and the general public.
- Plan and conduct all operations in a safe and environmentally responsible manner.
- Adhere to the highest professional and ethical standards in all activities.

- Support the execution of R&D missions with efficient, cost-effective business practices and support services.
- Acquire and sustain the intellectual and physical resources needed to explore challenging scientific and technical problems and provide innovative solutions.
- Collaborate with universities, industry, other DOE laboratories, other federal agencies, and state and regional organizations to create new opportunities.
- Communicate the value of ORNL's R&D activities to a broad audience.
- Respect the value of other people's time.

2.4 • Mission Execution

2.4.1 • Key R&D Activities

Science and Technology

ORNL's R&D in science and technology 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, nuclear physics, and high-energy physics. Activities span the following fields:

- Materials science and engineering, with emphasis on development of ceramics and composites, metals and alloys, surfaces and thin films, polymers, superconductors, and new techniques for materials synthesis, processing, and characterization
- Analytical and separations chemistry and chemical sciences, spanning chemical process fundamentals, chemical measurements and instrumentation, environmental monitoring and technology, hydrothermal solution chemistry and geochemistry, interface and surface science, materials chemistry, mass spectrometry research and applications, radioactive materials characterization, and actinide science
- Environmental sciences, integrating strengths in biogeochemistry, environmental biotechnology, environmental chemistry, ecosystem studies, geosciences, hydrology, and environmental assessment
- Fusion science and technology, including plasma theory, magnetic confinement experiments, plasma heating and fueling, atomic physics, and materials development
- Instrumentation and measurement science and technology
- Nuclear physics and nuclear astrophysics with radioactive ion beams
- 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, and bioengineering
- High-performance computing, with emphasis on computer and computational science, distributed computing, and informatics
- Social sciences, providing support for planning and policy decisions related to major energy and environmental issues

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
- Biomass energy, with a focus on sustainable biomass feedstock and conversion technologies
- Fossil energy, emphasizing applied materials, fuel cells, efficient turbine systems, and carbon sequestration
- Nuclear technology and safety

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 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

National Security

ORNL contributes to DOE's strategic goal of supporting nuclear security, promoting international nuclear safety, and reducing the global danger from weapons of mass destruction through activities 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
- Strategic computing for safe stockpile stewardship

2.4.2 • Major Facilities

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

- **Spallation Neutron Source (SNS).** The SNS, an accelerator-based neutron source now under construction by a team of DOE national laboratories, will be the world's most powerful facility for pulsed neutron scattering research when it is completed in 2005.

- **High Flux Isotope Reactor (HFIR).** The HFIR is one of the world's most powerful research reactor facilities. At its current operating power of 85 MW, it has a peak thermal neutron flux of 2.6×10^{15} neutrons per square centimeter per second, highest in the world. This gives the reactor unique capabilities for producing important radioisotopes and providing facilities for materials irradiation, neutron activation analysis, and neutron beam scattering studies.
- **Holifield Radioactive Ion Beam Facility (HRIBF).** The HRIBF is the first U.S. radioactive ion beam facility devoted to nuclear structure and nuclear astrophysics research. It is providing new information on nuclear properties and allowing researchers to make pioneering advances in understanding novas, supernovas, X-ray bursts, and other stellar explosions.
- **Mouse Genetics Research Facility (MGRF).** ORNL's MGRF employs expertise in mouse genetics and mutagenesis, phenotype screening, and high-throughput analytical technologies to generate and analyze mutations that add functional information to specific human DNA sequences. Its extensive stocks of mutant mice are a matchless resource for advancing the understanding of the complex mechanisms underlying the development and functioning of biological systems.
- **High Temperature Materials Laboratory (HTML).** The HTML houses several dedicated laboratories and special equipment for collaborative research on advanced ceramics and alloys. Extensive capabilities for materials characterization support advanced research by a broad user community representing DOE, universities, and industry.
- **Oak Ridge National Environmental Research Park (NERP).** ORNL resources for environmental research and education include the ≈20,000-acre NERP, which encompasses a sizable area of protected eastern deciduous forest that contains a number of rare and endangered plant and animal species and several major research facilities: the Walker Branch Watershed, the Throughfall Displacement Facility, the Global Climate Change Experimental Chambers, the Free Air Carbon Dioxide Enrichment Facility, and specialized hydrology field research sites.
- **Center for Computational Sciences (CCS).** The CCS provides resources for scientific computing and simulation through operation of powerful computers, development of data storage and access systems and facilities, and collaborative investigations of innovative computing architectures.
- **Buildings Technology Center (BTC).** Research on building thermal envelope systems and materials is conducted in the BTC, which provides world-class facilities for testing advanced building materials and construction strategies.
- **Radiochemical Engineering Development Center (REDC).** The REDC facilities provide transuranium actinide elements (Np, Pu, Am, Cm, Bk, Cf, Es, and Fm) for research endeavors at DOE national laboratories and installations, academic institutions, and industrial facilities.
- **Surface Modification and Characterization Research Center (SMACRC).** The SMACRC is used for fundamental studies of ion-solid interactions and ion beam and laser processing for advanced thin-film science and technology.
- **Shared Research Equipment (SHaRE).** The SHaRE program provides microanalytical facilities for studies in the materials sciences.

2.4.3 • 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. These partnerships provide ways to leverage ORNL's resources and increase its scientific productivity. They also provide an avenue for directing resources toward the regional economy; people and technology from ORNL have contributed to the creation of more than 70 companies that employ more than 2,000 people. The Office of Partnerships and Program Development (see Sect. 6) provides a focal point for many of these activities.

As an element in DOE's national laboratory system, ORNL works with other national laboratories. The Spallation Neutron Source project, described in Sect. 4.1.1, has been cited by DOE as an outstanding example of interlaboratory collaboration. R&D partnerships with other laboratories and with universities, industry, other government agencies, and international research institutions are carried out 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."

Partnerships are also a key element in ORNL's strategic objective of contributing to the community as a good neighbor, a resource for knowledge and technology, and a valued employer and partner.

2.4.4 • R&D Programs

As a multiprogram national laboratory, ORNL carries out R&D in support of all four major DOE missions: science and technology, energy resources, environmental quality, and national 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.

2.4.4.1 • Science and Technology

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

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) Upgrade, which are discussed in Sect. 4.1.

The BES **Materials Sciences** subprogram supports a comprehensive fundamental materials R&D effort in support of DOE's science and energy missions. An integrated, interdisciplinary approach is emphasized, including major research efforts in neutron scattering, synthesis and characterization of advanced materials, high-temperature materials, ceramic processing, superconductivity, surfaces and thin films, synchrotron research, ion beam and laser processing, and theoretical studies. The program benefits from access to unique, state-of-the-art materials research facilities and from close interactions with materials-related energy technology programs. Major research initiatives include the SNS and the neutron scattering upgrades at HFIR (both described in Sect. 4.1), the development of synchrotron beam lines at the Advanced Photon Source at Argonne National Laboratory, and a proposal for an Advanced Materials Characterization Laboratory (see Sect. 3.4.2).

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

ORNL is a leader in fundamental materials science and the development of advanced materials, processes, and characterization technologies. The SNS and the upgrades to the HFIR are addressing a long-term national need for improved neutron science facilities and will provide outstanding opportunities in many fields. A new focus at the HFIR, made possible by the new cold source, will be soft condensed matter research. New microbeam capabilities at the Advanced Photon Source will extend the understanding of materials phenomena to mesoscale length scales. Other new research directions include ultrahigh-temperature intermetallics, ceramic surfaces and interfaces, and the effects of reduced dimensionality and nanoscale geometries on materials properties. The proposed Advanced Materials Characterization Laboratory (see Sect. 3.4.2) will address ORNL and national needs in materials characterization and synthesis.

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 Partnership for a New Generation of Vehicles 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 activation analysis, materials irradiation, the production of isotopes, and neutron scattering R&D. Neutrons from the HFIR are vital to research in the materials sciences, chemical sciences, magnetic fusion, and biology programs at ORNL and for external users and collaborators. Each year approximately 400 researchers use its facilities. Activities at the REDC involve the development and use of production processes and product forms for radioisotopes, predominantly the isotopes of transuranium elements.

The Chemical Sciences 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, and actinide science. 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; unraveling the systematics of the solid-state behavior of actinide elements and compounds; relating the thermodynamic properties of aqueous solutions at extreme conditions to molecular structure; and developing advanced battery concepts.

Research in experimental and theoretical atomic physics completes the Chemical Sciences portfolio at ORNL. This program operates the Atomic Physics EN Tandem Van de Graaff accelerator and the Electron Cyclotron Resonance Ion Source Facility for low-energy atomic physics. The experimental effort is focused on studying interactions of highly charged or molecular ions with gas and solid targets and with electrons. Collision energies range from 2 meV to 33 TeV. Intimately coupled with the experimental work are theoretical studies of the dynamics of strongly perturbed atomic systems, which involve the development of new physical models and mathematical and computational techniques. Strong connections to experimental programs at ORNL and other laboratories are maintained; particular attention is focused on fundamental and complex systems that play a role in energy research.

The BES **Engineering and Geosciences** subprogram sponsors two engineering research activities at ORNL: an investigation of the engineering principles governing the operation of liquid-liquid emulsion bioreactors and the Center for Engineering Systems Advanced Research (CESAR). CESAR's primary mission is to develop a core of excellence in the area of intelligent systems technology, supporting the needs of DOE (see Sect. 3.4.5) and other customers. Geoscience research at ORNL focuses on fundamental geochemical processes that control matter and energy transport in the earth's crust.

Biological and Environmental Research—KP

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

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

Research in the life sciences addresses the understanding of complex biological systems and includes functional genomics and mammalian genetics, biochemistry, biophysics, toxicology and risk analysis, nuclear medicine, biomedical technology development, and computational biology and informatics. The major Laboratory initiative in complex biological systems, described in Sect. 4.2, is an integrated activity that draws on resources from these and other ORNL programs.

Environmental science research covers biogeochemistry, environmental biotechnology, 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 (see Sect. 3.4.3) and global climate change and to strategies for carbon management and sequestration.

ORNL plays a key role in environmental data systems for DOE's research. The Atmospheric Radiation Measurement (ARM) Program sponsors a data archive that stores the massive quantities of data collected as part of this multiyear observation project; the archive also provides the general scientific community with ready access to the data. The Carbon Dioxide Information Analysis Center, sponsored by OBER, serves as one of the world's principal repositories for data and is the focal point for the compilation and dissemination of numerous critical databases, including national fossil-fuel CO_2 emission time series and the Mauna Loa atmospheric CO_2 concentration record. In August 1999, the OBER Environmental Sciences Division announced the formation of the National Center for Research on Enhancing Carbon Sequestration in Terrestrial Ecosystems (CSITE), a distributed research center that includes ORNL, Pacific Northwest National Laboratory, and Argonne National Laboratory, with collaborators from several universities and other research institutions.

ORNL is expanding research that focuses on harnessing microbial processes to remediate radionuclide and metals contamination in the subsurface in support of DOE's Natural and Accelerated Bioremediation Research Program (NABIR). Research on the microbial genome (see Sect. 4.2.3) is emphasizing organisms important to global change, carbon sequestration, marine biotechnology, and bioremediation.

Three user facilities contribute to the ORNL BER Program: the Mouse Genetics Research Facility, the Oak Ridge National Environmental Research Park, and the Bioprocessing R&D Center. The ORNL Center for Biotechnology provides a coordinated focus for the Laboratory's extensive biotechnology activities in the areas of biomedical sciences, environmental sciences, and bioprocessing (see Sect. 6.2.2.2). The ORNL Center for Global Environmental Studies integrates the Laboratory's science and technology to understand environmental processes and support sustainable development.

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 ORNL Center for Computational Sciences 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 resources and expertise to support DOE's missions in science and national security.

The AMS subprogram supports research in parallel processing algorithms; tools to facilitate the use of parallel and distributed computing systems; and development of applied mathematical, statistical, and computational methods for use in areas requiring high-end computing, such as solid and fluid dynamics, climate dynamics, and biophysics. 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 neutron scattering virtual laboratory based on the DIXIE instrument at the HFIR; the ACTS

Scientific Template Library; the Electronic Logbooks project; and the Collaborative Management Environment project.

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

ORNL's Collaborative Technologies Research Center provides a means for ORNL to team with universities, other laboratories, and industry partners in building capabilities for telepresence and collaborative environments. It will play a role in the strategic objective to develop and integrate skills and facilities for computing, modeling, and simulation.

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

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. ORNL staff members conduct experimental research on toroidal confinement of high-temperature plasmas on several large tokamaks and stellarators in the United States and other countries. Theoretical research on high-temperature plasmas uses state-of-the-art computing methods (see Sect. 4.3.2.1) 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; and conducts a variety of R&D projects applying fusion-related technologies and expertise to other fields such as plasma processing and waste disposal.

ORNL's expertise is well matched to the increased emphasis being placed on innovative confinement concepts by the U.S. fusion program. The U.S. spherical torus program, which originated at ORNL, is now centered on the National Spherical Torus Experiment

(NSTX) at the Princeton Plasma Physics Laboratory (PPPL). ORNL is a major participant in the NSTX physics program.

ORNL is also deeply involved in the growing national stellarator program. Two approaches—quasi-axisymmetry (QA) and quasi-omnigeneity (QO)—hold promise for the development of compact stellarators. ORNL is partnering with PPPL to propose the National Compact Stellarator Experiment at PPPL, which would test the QA approach, and is working with PPPL and the University of Texas to propose a complementary facility, the Quasi-Omnigeneous Stellarator (QOS), to be built at ORNL.

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

Nuclear Physics—KB

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

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

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 nuclear structure theory program. ORNL has unique resources for the construction and operation of a next-generation RIB facility, for which the HRIBF can be considered a prototype (see Sect. 3.4.1).

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. 2.4.4.3).

Work is under way to study the feasibility of using ORELA to test the performance of actinide targets designed for use in high-power beams (e.g., those at an advanced RIB facility) and to explore the use of ORELA for production of radioactive species from the fission of actinide targets. Preliminary results are very encouraging; this work might lead to development of a high-power target test facility and a production facility for neutron-rich RIBs.

High Energy Physics—KA

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

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.

2.4.4.2 • Energy Resources

Energy Efficiency and Renewable Energy

ORNL's Energy Efficiency and Renewable Energy (EE/RE) Program facilitates R&D on energy efficiency and renewable energy technologies. The major source of program funding is DOE'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).

Four energy-related national user facilities are available to researchers: the Bioprocessing R&D Center, the Buildings Technology Center (BTC), the High Temperature Materials Laboratory, and the Materials Processing Laboratory User Center.

ORNL is a partner in the Energy Efficiency and Renewable Energy Network, a joint project involving DOE-EE, Argonne National Laboratory, ORNL, and the National Renewable Energy Laboratory. ORNL also provides U.S. representation to three projects of the International Energy Agency: the Center for the Analysis and Dissemination of Demonstrated Energy Technologies (CADDET), which maintains an international database of successful, demonstrated energy technologies and facilitates information exchange; the Greenhouse Gas Technology Information Exchange (GREENTIE), which maintains a directory of organizations and technologies that promote the reduction of greenhouse gas emissions; and the Heat Pump Programme, which carries out a strategy to accelerate the use of heat pumps in all applications where they can reduce energy consumption.

The EE/RE Program addresses four major R&D areas: buildings, industry, power, and transportation.

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

The nine most energy-intensive industries—agriculture, aluminum, chemicals, forest products, glass, mining, metalcasting, petroleum refining, and steel—participate in DOE's Industries of the Future initiative, which assists these industries in cutting their nonproductive energy use and environmental costs. Development of new materials that can better withstand the high temperatures and highly corrosive environments often found in industrial processes is a key area of research. In support of DOE's **industrial technologies** efforts, ORNL leads materials R&D for ultrahigh-efficiency, clean, cost-competitive gas turbines. Technology support to the DOE Motor, Steam, and Compressed Air Challenge Programs includes the development of measurement and validation tools and techniques. New equipment and processes are investigated, ranging from improvements in heat transfer equipment to "bioreactors" that convert sugars (instead of today's petroleum feedstocks) to industrial chemicals. Other research is concerned with heat pump and chiller technologies.

During the past several decades, electricity's share of U.S. primary energy use has been steadily increasing, to about 35% of the total in 1994. 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 high-temperature superconductivity; power transmission and distribution, including system reliability and health effects of electromagnetic fields; power electronics; development of biopower feedstocks; hydrogen production, use, and storage; geothermal studies; hydropower environmental mitigation studies; electric utility studies; and international energy collaborative programs.

Transportation R&D in the ORNL EE/RE Program includes materials, ignition and combustion, alternative fuels (including biofuels), transportation data and policy analysis, and innovative manufacturing and finishing processes. Most of the transportation R&D is related to the Partnership for a New Generation of Vehicles, which has three goals: to significantly improve national competitiveness in manufacturing, to pursue changes in today's vehicles that will improve efficiency and lower emissions while maintaining safety and performance, and to achieve, within a decade, improvements in fuel efficiency up to three times that of the average 1994 Taurus/Concorde/Lumina–type sedan, at a competitive price. R&D funded by DOE is the cornerstone for a broad transportation program that supports the needs of other sponsors, as described in Sects. 2.4.4.6 and 3.4.6.

ORNL's Bioenergy Feedstock Development Program conducts R&D for both the power sector and the transportation sector. ORNL develops new energy crops with increased yields, pest and disease resistance, and drought tolerance for conversion to fuels and power. The Laboratory also addresses the resource, economic, and environmental issues related to biomass feedstocks. ORNL addresses technology needs for using biomass in existing power plants to supplement or replace coal and is working with the National Renewable Energy Laboratory to propose a National Bioenergy Center that would support the development of a viable bioenergy and biologically based products industry.

Fossil Energy

ORNL programs for DOE's Office of Fossil Energy (DOE-FE) cover research in coal, gas, petroleum, and innovative clean coal technology, plus support to the Strategic Petroleum Reserve.

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

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

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

DOE-FE and DOE-SC have established a formal working group to coordinate carbon management science and sequestration technology research. ORNL is participating in this group and expects to play a major role in these areas (see Sect. 4.4.3.4).

Nuclear Energy, Science and Technology

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

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

DOE's Nuclear Energy Research Initiative (NERI) provides funds to four ORNL projects: (1) the development of an advanced reactor concept, the demand-driven nuclear energizer module; (2) the development of a new paradigm for cost-effective development and reliability assessment of integrated plant control, monitoring, and communication systems (in collaboration with the University of Tennessee and North Carolina State University); (3) the development of improved burnable poisons for commercial nuclear power reactors; and (4) the mapping of flow localization processes in deformation of irradiated reactor structural alloys. ORNL is also participating in a NERI project led by the University of Michigan.

ORNL supports the production of parts for radioisotope power systems supplied to the National Aeronautics and Space Administration (NASA), providing the materials processing and precision fabrication required to produce the iridium clad vent sets and the carbon-carbon holders. In support of DOE's evaluation of alternatives for the domestic production of ^{238}Pu for future space mission, ORNL is studying the possibility of meeting long-term needs for an assured supply of ^{238}Pu by irradiation of ^{237}Np targets, both in the Advanced Test Reactor (ATR) at the Idaho National Engineering and Environmental Laboratory and in the High Flux Isotope Reactor (HFIR) at ORNL. Drawing on capabilities and facilities available through its Radiochemical Engineering Development Center (REDC), ORNL would fabricate the ^{237}Np targets for both ATR and HFIR irradiations and would provide chemical processing of the targets for material recovery.

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

ORNL supports key objectives in uranium programs through activities such as developing technology and providing systems for the verification of highly enriched uranium blend-down in Russian Federation facilities and serving as lead laboratory for the identification and development of beneficial uses for depleted uranium (DU). At the request of DOE-NE and the DOE Oak Ridge Operations Office, ORNL is organizing a Depleted Uranium Hexafluoride Program to provide DOE with technical support for DU disposition. Conversion and use or management of the 700,000 metric tons of DU stored at DOE's gaseous diffusion plant sites is a significant challenge. Activities in FY 1999 include program planning and analysis, R&D road mapping, and technical support for conversion plant procurement activities. In the longer term, ORNL expects to implement and manage an R&D program to establish the technical basis for use and management of DU. A program manager has been appointed, and a multidivisional team will provide technical support to DOE and carry out program activities.

Power Marketing Administrations

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

Energy Information Administration

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

2.4.4.3 • Environmental Quality

Environmental Management

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. ORNL's Office of Environmental Management Programs provides technical and financial coordination for environmental restoration, waste management, and technology development. Transportation R&D, pollution prevention, and facility transition programs are also under the jurisdiction of this organization.

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 (EM) program under a management and integration contract (see Sect. 5.1.5). Much of the R&D, however, serves more than one DOE site, including sites outside Oak Ridge.

ORNL supports DOE-EM through the development and implementation of better, safer, and less expensive alternatives to existing technologies, with the aim of providing workable solutions to previously intractable problems. Efforts sponsored by the DOE-EM Office of Science and Technology focus on five major problem areas: subsurface contamination; mixed waste characterization, treatment, and disposal; high-level waste tank remediation; facility deactivation and decommissioning, and nuclear materials disposition. Work is also performed in several cross-cutting areas: characterization, monitoring, and sensor technologies; separations and processing technologies (see Sect. 3.4.4); and robotics technologies (see Sect. 3.4.5). 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.

Recent achievements include robotic technologies for facility decontamination and for retrieving radioactive waste from underground tanks, advances in tank waste mobilization and slurry transport and monitoring, improved separations processes for aqueous waste, new techniques for in situ treatment of contaminated groundwater, and faster and more accurate waste characterization. Basic research is improving the understanding of the role of colloids in subsurface transport and retention of contaminants; it has also led to the development of a highly sensitive microsensor for detecting contaminants in various media. Increasing emphasis is being placed on supporting the application of R&D to EM problems through communication and interaction with waste management or remedial action project staff.

ORNL also supports DOE's Nuclear Criticality Safety Program (NCSP), which was developed in response to Defense Nuclear Facility Safety Board Recommendations 93-2 and 97-2. The NCSP is a cross-cutting, multilaboratory program, led by DOE's Office of Defense Programs with additional funding from other DOE organizations. ORNL efforts are primarily funded by DOE-EM; DOE-SC and the DOE Office of Environment, Safety and Health also contribute to the NCSP budget. ORNL 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. ORNL coordinates the work program of the Analytical Codes Task by providing capability maintenance and training and user assistance in the SCALE/KENO code system. ORNL is also performing another NCSP Task, “Guidance for Applicability of Bounding Curves/Data.”

Environment, Safety, and Health

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

2.4.4.4 • National Security

Defense Programs

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

ORNL produces ^{252}Cf in the HFIR through an Industrial Sales/Loan Program cosponsored by DOE-SC. Transuranium element isotopes are recovered from Mark 42 targets, purified, and used in weapons diagnostics at Los Alamos National Laboratory. ORNL’s Radiochemical Development Facility (Building 3019A) provides shielded, safeguarded storage of ^{233}U, which has been used in diagnostics for weapons testing by DOE-DP. In response to the Defense Nuclear Facility Safety Board’s Recommendation 97-1, “Uranium-233 Storage Safety at Department of Energy Facilities,” ORNL has prepared a ^{233}U Storage Alternative Trade Study (ORNL/M-6606, September 1998) and a Final Oak Ridge National Laboratory Site Assessment Report on the Storage of ^{233}U (ORNL/TM-1999/86, June 1999).

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

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

Fissile Materials Disposition

Under the sponsorship of the DOE Office of Fissile Materials Disposition, ORNL is DOE's lead laboratory for nuclear-based technologies for fissioning surplus plutonium in existing power reactors in the United States, Russia, and possibly Canada. ORNL's roles for the disposition of U.S. materials include (1) R&D needed to convert and license U.S. light water reactors (LWRs) for use in turning surplus weapon-grade plutonium into spent fuel and (2) technical support to the DOE procurements of a mixed-oxide (MOX) fuel fabrication facility and irradiation services to burn MOX fuel in commercial LWRs. ORNL was recently identified in the *Surplus Plutonium Disposition Final Environmental Impact Statement* (DOE/EIS-0283, November 1999) as the preferred site for postirradiation examination of MOX fuels.

Critical research at ORNL includes tests to define compatibility issues associated with interactions between gallium fuel impurities and LWR clad materials. ORNL is also managing a multilaboratory, multinational irradiation test program to demonstrate the feasibility of using CANDU reactors for the fissioning of U.S. and Russian surplus plutonium. ORNL is responsible for managing and cooperating with Russia in developing the technology needed to fission Russian plutonium in Russian and Ukrainian VVER-1000 pressurized water reactors and in performing the design and safety analyses needed to convert the Russian BN-600 liquid metal reactor from a plutonium breeder to a plutonium burner. Finally, ORNL is responsible for the technical effort to assist DOE in collecting and analyzing data for the environmental impact analysis of options for disposition of surplus ^{233}U.

Nonproliferation and National Security

The Office of Nonproliferation and National Security (DOE-NN) supports R&D activities and technical assessments related to national security requirements. Much of this work is performed through partnerships with the Oak Ridge Y-12 Plant. 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.

2.4.4.5 • Other DOE Programs

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

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

ORNL assists the Federal Energy Regulatory Commission (FERC) in (1) environmental, economic, and engineering assessments that support licensing of nonfederal hydroelectric projects, and (2) studies related to compliance with FERC license conditions or other environmental regulations at existing projects. Relicensing of existing projects has become a major effort for the FERC, and ORNL staff are working to define methods to enhance an environment that may have been affected by 50 years of hydropower operation.

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

2.4.4.6 • Work for Others

Federal Organizations

Nuclear Regulatory Commission • ORNL supports the Nuclear Regulatory Commission (NRC) in nuclear safety, safeguards, and environmental protection activities and by providing a technical basis for the NRC's licensing and other regulatory actions and decisions. Approximately 40 projects are administered through the NRC Programs Office; work is carried out by nine ORNL divisions and two Lockheed Martin Energy Systems, Inc., organizations. These projects are carried out in agreement with the Memorandum of Understanding established between DOE and NRC in 1978 and 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 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. The Accident Sequence Precursor (ASP) program identifies nuclear power plant events that are considered precursors to accidents with the potential for severe core damage and uses risk assessment methodologies to determine the quantitative significance of the events. ORNL is assisting in the resolution of operational performance issues, benchmarking the operating records of power plants for diagnostic assessments, trending events, providing technical assistance, and responding to inquiries from NRC staff on operational and safety-related issues. ORNL operates and maintains the Sequence Coding and Search System (SCSS), the NRC's official database of reportable operational events at commercial nuclear power plants. This highly structured system, available to NRC staff via the World Wide Web, provides detailed searching of operational events. SCSS supports the ASP program, the NRC's Performance Indicator Program, quantification of common-cause failures, and hundreds of ad hoc queries each year from NRC staff. ORNL also supports the Performance Indicator Program by evaluating operational events to identify and document potential programmatic deficiencies and licensee corrective actions so as to readily ascertain adverse trends in performance.

Research areas for NMSS include criticality safety, shielding and thermal analyses of nuclear fuel facilities and cask designs, environmental review of licensee facilities, and review of terminated materials handling license files.

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 with Lockheed Martin Energy Systems, Inc., and include basic and applied research and technology demonstration programs.

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

Work continues to develop miniaturized sensors, intelligent sensors on a chip, and battlefield-portable mass spectrometers for point contact and stand-off detection of chemical and biological agents. New instrumentation and sensors are also being developed to improve detection of land and marine mines from land-, air-, and marine-based systems. Some of this work is conducted in collaboration with other DOE national laboratories (see Sect. 6.2.2.2).

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

Autonomous and teleoperated robotic systems are developed for remote navigation in hazardous environments for site characterization and restoration and for safe handling of hazardous materials. Remote handling technologies are also used to rearm ammunition for military ground combat vehicles, aircraft, and air defense missile systems. These efforts draw on ORNL capabilities in robotics and intelligent machines (see Sect. 3.4.5).

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

National Aeronautics and Space Administration • The NASA Earth Observing System Data and Information System (EOSDIS) is a key component of the U.S. Global

Change Research Program. ORNL is one of nine Distributed Active Archive Centers through which the scientific research community can acquire data and information from EOSDIS. ORNL is also supplying radio-frequency technology and expertise in high-temperature superconductors for an advanced rocket engine and assisting in data compilation on the growth of vegetation.

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

U.S. Environmental Protection Agency • ORNL's work for the EPA addresses numerous health and environmental problems and issues. Activities include evaluation of the cost-effectiveness of reducing nitrogen oxide emissions as a means of ozone control; support for ecological risk activities; 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; maintenance of the Chemical Unit Record Estimates (CURE) database; field validation of analysis methods; and development of reference dose and reportable quantity profiles to reduce uncertainty in risk assessments.

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

- Studies of spatial gradients in nutrient cycling and their effect on stream ecosystem stability. The results will benefit studies of disturbed aquatic systems on the Oak Ridge reservation that are being conducted in concert with remedial actions.
- Research to evaluate the scientific basis for assumptions used in risk assessment. Results are intended for use by federal agencies responsible for regulating human exposure to chemical carcinogens.
- Development of methods for maintaining genetic lines of *Drosophila* in a frozen state.
- Free-air carbon dioxide enrichment (FACE) studies of a closed-canopy deciduous forest at the ORNL FACE Facility in the Oak Ridge National Environmental Research Park (see Sect. 3.4.5).

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

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

U.S. Agency for International Development • ORNL serves 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.

U.S. Department of Transportation • The Department of Transportation provides funding to the National Transportation Research Center (see Sect. 3.4.6) and supports the ORNL Center for Transportation Analysis. ORNL assists the Federal Highway Administration, the National Highway Traffic Safety Administration, the Office of Pipeline Safety, the Federal Transit Administration, the Federal Aviation Administration, and the Bureau of Transportation Statistics in research areas that include development of freight and passenger demand models; assessment of data quality and data consistency of highway statistics; development of data collection methods and advanced data management systems to improve data integrity and availability; analysis of nationwide surveys to address issues in current or future national transportation policies; development of methods to statistically link data sources to study intermodal traffic; and research on intelligent transportation systems. ORNL also provides technical assessment of oil and gas pipeline systems throughout the United States for compliance with regulatory standards.

Other Federal Agencies • ORNL provides technical support to a variety of other federal agencies, including the U.S. Department of Agriculture, the U.S. Department of Commerce, the U.S. Department of 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 continues to assist the National Park Service in evaluating the environmental impact of extensions of the Foothills Parkway, adjacent to the Great Smoky Mountains National Park.
- In support of the Coastal Change Analysis Project, sponsored by the Coastal Services Center of the National Oceanic and Atmospheric Administration, ORNL conducts R&D on land-cover monitoring in the coastal regions of the United States.
- ORNL is assisting TVA in an assessment of the potential for biomass energy within the TVA power system.
- Support is provided to the Bureau of Labor Statistics in artificial intelligence systems to provide estimates of consumer prices index and survey automation.
- ORNL provides support in environmental management of water resources to several federal agencies. For example, ORNL staff serve as technical advisors to the Bureau of

Indian Affairs and the U.S. Army Corps of Engineers on environmental issues such as hydropower impacts on fish and wildlife and instream flow policies.

- ORNL serves as the lead DOE laboratory for technical support to the U.S. Chemical Safety and Hazard Investigation Board. Activities include assisting the board in conducting accident investigations, carrying out special studies of safety issues in the chemical industry, supporting the development and analysis of accident databases, and assisting the board in transferring to the chemical industry knowledge and technology that will reduce the occurrence and severity of accidents.
- Under the sponsorship of the interagency Strategic Environmental R&D 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.

Nonfederal Organizations

ORNL performs research for and in collaboration with many nonfederal entities, both public and private (see Sect. 6.1). These efforts support DOE's aims in developing partnerships and applying the resources of the national laboratories to issues and problems of national importance.

Electric Power Research Institute • The Electric Power Research Institute (EPRI) funds research at ORNL in areas related to the generation and efficient use of environmentally acceptable electric energy. This research includes a program on compensatory mechanisms in fish populations, complementing work for DOE's Hydropower Program; analysis of the potential of biomass feedstock for electric power plants, which involves interaction with DOE's Bioenergy Feedstock Development Program; a project co-funded by DOE and EPRI to develop and demonstrate intelligent control systems for nuclear power plants; and technology development in high-temperature structural design methods and fracture assessment procedures for advanced reactors and other high-temperature power plant components, the results of which support DOE's reactor programs. Associated with EPRI research is work funded by Babcock and Wilcox (B&W) 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. 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.

2.4.4.7 • Laboratory Directed R&D Program

ORNL's Laboratory Directed R&D (LDRD) Program provides financial support for innovative R&D ideas that, while within the general mission of the Laboratory, have no direct programmatic funding. Such ideas can and do lead to productive new technical directions (see Sect. 6.2.1). The program operates under the authority of DOE Order 413.2, “Laboratory Directed Research and Development” (March 5, 1997). It is funded by DOE through an overhead charge to all other Laboratory programs. All LDRD project funding requires the approval and authorization of the Laboratory director. The annual program plan for the LDRD Program, which is prepared and submitted to DOE-SC in accordance with DOE Order 413.2, serves to request LDRD funding for the Laboratory and to provide a general description of and justification for the LDRD program. The *ORNL Laboratory Directed Research and Development Program: Annual Report to the Department of Energy Summarizing Fiscal Year 1998* (ORNL/PPA-99/1, March 1999) provides a program overview, funding summaries, and project summaries for the LDRD Program.

3 • Laboratory Strategic Plan

This strategic plan is designed to position the Oak Ridge National Laboratory (ORNL) to support the U.S. Department of Energy (DOE) in achieving the goals and commitments outlined in the Department's Strategic Plan. It outlines those areas on which ORNL will focus attention to ensure that it continues to deliver cost-effective scientific and technological performance to DOE and the nation.

Strategic goals (summarized in Table 3.1) address ORNL's enduring missions as a DOE science, technology, and energy laboratory. **Objectives** describe strategic activities required to accomplish the goals. The goals and objectives chart a course for the next 10 years. **Strategies** define requirements linked to each objective and are targeted toward the next 3 to 5 years.

Implementation plans have been developed to carry out strategies; these plans include performance measures and targets for the near term. Table 3.2 presents milestones that are most critical for the Laboratory in the next 1 to 5 years.

3.1 • Vision

ORNL envisions 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, and its effects on human health and the environment.

Taking advantage of the expanding opportunities in "science at the boundaries" will require both

- sustained excellence within the Laboratory's traditional disciplines and
- innovative support for interdisciplinary efforts to understand the complexity and diversity of the world in which we live.

Table 3.1
ORNL strategic goals

1. Enhance capabilities for leading-edge research and development
2. Demonstrate sustained excellence in the delivery of scientific advances and technological innovations that support the missions of the Department of Energy
3. Provide an environment in which science and technology can flourish
4. Demonstrate excellence in all aspects of Laboratory management and operations

Table 3.2
Critical milestones for ORNL

- Support the design and construction of the Spallation Neutron Source as the nation's premier tool for neutron scattering research and develop innovative programs to take advantage of its capabilities
- Complete the upgrade of the capabilities of the High Flux Isotope Reactor and use them more effectively for neutron scattering experiments requiring steady-state beams and for radioisotope production, materials irradiation, and neutron activation analysis
- Construct the Laboratory for Comparative and Functional Genomics to house the Mouse Genetics Research Facility and serve as the anchor facility for the Center for Biological Sciences
- Provide the critical enabling infrastructure for a new initiative in nanoscale science, engineering, and technology
- Establish a well-integrated and effective integrated safety management (ISM) program
- Develop an effective plan for consolidating ORNL operations at the main Laboratory site
- Complete the reengineering of research support services

The strategic goals, and the objectives and strategies associated with them, will equip ORNL to move toward its vision of advancing the frontiers of science and technology through broad interdisciplinary research and development (R&D) programs that answer fundamental questions, solve technical problems, and address societal needs.

3.2 • Strategic View

The ORNL strategic plan is based on the following expectations and assumptions about the world in which the Laboratory operates.

ORNL expects to 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 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 ORNL's portfolio. ORNL will actively seek new opportunities to apply its 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 its knowledge and technologies to the marketplace, improving the utilization of its facilities and expertise, maintaining its specialized capabilities, and broadening its 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 R&D 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.

ORNL will maintain its focus on continually improving its ability to execute its mission assignments, to operate safely and efficiently at reasonable cost, and to sustain and enhance its distinctive strengths. Critical assets—including a diverse and talented staff, state-of-the-art research facilities, and specialized capabilities—will be protected and enhanced. 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.

Public concerns about safety and security, both locally and nationally, will lead to increased scrutiny of Laboratory operations. The performance-based contract between DOE and the Laboratory's management and operating contractor will provide explicit measures for assessing the quality of the Laboratory's work, supported by processes for improving business management, life cycle asset management, and cost efficiency.

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 efforts in strategic planning and performance-based management, which respond to GPRA requirements, currently include an update of the DOE Strategic Plan and the strategic plans of DOE programs, the development of R&D portfolios for each of DOE's business lines, the development of road maps for critical technologies, and other activities that will be taken into account in ORNL's 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 growing 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 ORNL's ability to carry out its strategic plan. 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 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 will offer opportunities for increased deployment of renewable energy technologies, nuclear power, and other clean energy systems, but it will also heighten concerns about the cost, reliability, safety, and environmental impact of systems for the production, transmission, and distribution of energy.

- 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.

3.3 • Goals, Objectives, and Strategies

Goal 1. Enhance capabilities for leading-edge research and development

ORNL will address future national needs for science and technology through four major thrusts, represented by the following objectives, that will create and apply unparalleled capabilities for addressing scientific and technical problems of national and global significance.

Objective 1.1 Enhance ORNL’s capabilities for neutron science and use them to deliver new insights into the nature, structure, and behavior of materials

Strategies:

- Support the design and construction of the Spallation Neutron Source project as the nation’s premier tool for neutron scattering research and develop innovative programs to take advantage of its capabilities
- Complete the upgrade of the capabilities of the High Flux Isotope Reactor and use them with increased effectiveness for neutron scattering experiments requiring steady-state beams and for radioisotope production, materials irradiation, and neutron activation analysis
- Establish a world-class neutron scattering user program

Objective 1.2 Develop innovative means for observing and understanding the functioning of complex biological systems

Strategies:

- Develop the ORNL Center for Biological Sciences to integrate current and future research programs in functional genomics, structural biology, proteomics, and systems biology
- Integrate and apply capabilities in neutron scattering, mass spectrometry, and computational biology to advance the understanding of biomolecular structure
- Develop tools and technologies for analyzing the function of systems of genes and their interrelationships
- Provide computing and information tools needed to analyze and manage the data produced by large-scale genome sequencing
- Through the Joint Institute for Biological Sciences, foster regional and national collaborative efforts to explore emerging problems in the biological sciences

Objective 1.3 Develop and integrate skills and facilities for computing, modeling, and simulation and apply these integrated resources to DOE's needs in science and technology

Strategies:

- Leverage the established emphasis on high-end and distributed computing and participation in national initiatives
- Increase laboratory-wide level of expertise in modeling, simulation, and numerical methods
- Enhance the accessibility of ORNL's high-performance computational power, both within ORNL and throughout the DOE research community
- Maintain ORNL's reputation in computer science and enabling technologies

Objective 1.4 Develop a comprehensive and systematic approach to meeting the growing global need for energy services in environmentally sustainable ways

Strategies:

- Develop an integrated understanding of the science and technology needed to advance the development of affordable, widely available clean energy systems that respect health and the environment
- Develop new R&D capabilities for analysis and assessment of technological, environmental, and socioeconomic factors in the development and deployment of clean energy systems
- Integrate ORNL programs and projects to create a comprehensive resource for the development and implementation of clean energy systems

Goal 2. Demonstrate sustained excellence in the delivery of scientific advances and technological innovations that support the missions of the Department of Energy

ORNL's multidisciplinary R&D programs will support DOE missions in science and technology, energy, environmental quality, and national security. Objectives for this goal reflect the principal strategic activities that the Laboratory will conduct in delivering the science and technology critical to the success of DOE's mission and the nation's science base.

Objective 2.1 Create and apply knowledge and technology to develop technical options that will improve the efficiency, reliability, and safety of the nation's energy system and expand future energy choices

Strategies:

- Support the development of biomass as an environmentally friendly, renewable source of energy through support for DOE's Integrated Bioenergy Initiative
- Collaborate with industry in the development of a new generation of efficient design, construction, and operation options for commercial buildings
- Develop technologies to remove the barriers imposed by the environmental impacts of fossil fuel production and use

- Broaden the application of ORNL's capabilities in transportation technology through activities that capitalize on the synergies of multiple sponsors and industrial partners
- Collaborate with industry in the development of improved materials for and energy applications of high-temperature superconductors that will contribute to clean power systems

Objective 2.2 Apply an integrated theoretical, experimental, and computational approach to understanding and exploiting the physical, chemical, and mechanical properties of materials

Strategies:

- Maintain an appropriate environment for conducting the R&D essential for understanding materials and materials-related processes and phenomena
- Apply computational tools to accelerate the development of new, technologically advanced materials that can improve the efficiency and economy of clean energy production and use, contribute to new technologies, and lead to new products
- Improve capabilities for visualization and manipulation of materials on the molecular level

Objective 2.3 Extend the understanding of the fundamental properties of matter at the atomic, nuclear, and subnuclear levels through experimental and theoretical research and data compilation and evaluation

Strategies:

- Broaden the understanding of nuclear structure, nuclear astrophysics, and nuclei subjected to extreme temperatures, rotational frequencies, and pressures
- Work with university collaborators to develop a proposal for construction of the Oak Ridge Large Neutrino Detector (ORLaND) at the Spallation Neutron Source to search for neutrino oscillations

Objective 2.4 Integrate expertise in chemistry and chemical sciences and technologies to examine and understand energy-intensive processes and to develop new and improved processes that conserve energy, protect the environment, and facilitate threat reduction

Strategies:

- Integrate 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
- Coordinate capabilities in mechanistic chemistry, catalysis, hydrothermal chemistry, and geosciences to contribute to definition and exploration of new and improved processes
- Leverage advances in analytical science, particularly microinstrumentation and mass spectrometry, to facilitate research and create new tools

Objective 2.5 Create and apply knowledge and technology to protect and improve human and environmental health

Strategies:

- Apply ORNL resources in biology, chemistry, microbiology, computing, physics, and engineering to problems in health sciences and technology

- Develop innovative technologies and applications in nuclear medicine, biotechnology, and biomedical instrumentation
- Create an integrated program for the development of the Virtual Human
- Develop new scientific approaches and facilities to extend the understanding of the impacts of energy development and use on the environment and to support the development of innovative solutions to major environmental issues
- Extend the scientific understanding of atmospheric, ecological, and geohydrological processes to create solutions to current environmental stresses and prevent future problems
- Develop knowledge, data systems, measurement technologies, and methods for assessing environmental risks that allow for improvements in managing and restoring systems and protecting human health

Objective 2.6 Advance plasma science and fusion technology

Strategies:

- Design, construct, and operate an innovative magnetic fusion experiment, the quasi-omnigeneous stellarator, as a complementary element of the national fusion energy sciences program
- Continue and expand ORNL participation in national and international fusion collaborations
- Develop near-term applications for fusion science and technology in collaboration with government and industry partners

Objective 2.7 Expand the application of ORNL's distinctive capabilities in nuclear science and technology

Strategies:

- Contribute knowledge and technology to reduce long-term barriers to the use of nuclear energy
- Develop, produce, and deliver stable and radioactive isotopes
- Develop power supplies for space and terrestrial applications
- Deliver systems, technologies, software, and data for promoting nonproliferation and international nuclear safety
- Provide technologies and data to support risk-informed regulation of the U.S. nuclear enterprise

Goal 3. Provide an environment in which science and technology can flourish

ORNL will continue “bringing science to life" by providing an environment that fosters excellence in R&D. Objectives for this goal outline the means by which ORNL will acquire, sustain, and expand the resources that it needs to support this environment for excellence.

Objective 3.1 Sustain and extend ORNL’s ability to contribute to the science and technology base needed to accomplish DOE missions and other national goals

Strategies:

- Develop and implement a living science and technology roadmap for ORNL’s future
- Provide the critical enabling infrastructure for a new initiative in nanoscale science, engineering, and technology
- Increase the scope of ORNL’s activities in robotics and intelligent machines and broaden their application to long-term needs in manufacturing, hazardous and remote operations, and monitoring and surveillance
- Integrate capabilities in photonics, electronics, materials, signal processing, sensor development, and simulation to provide unique measurement and control systems

Objective 3.2 Create opportunities for focused, mission-driven growth

Strategies:

- Develop and sustain external relationships that leverage resources and expand research opportunities
- Apply discretionary resources to key areas of opportunity
- Secure new customers for Laboratory capabilities and technologies
- Improve the management and protection of intellectual property to maximize its value to the Laboratory

Objective 3.3 Enhance critical skills and organizational vitality

Strategies:

- Align “people strategies” with organizational strategies
- Improve the Laboratory’s ability to provide competitive salaries and benefits
- Recognize and promote the competitive advantage of diversity in the workplace
- Increase opportunities for the development of a diverse workforce
- Create and administer progressive work-life programs that meet work force needs
- Expand the availability of educational opportunities that attract talented researchers to ORNL
- Focus student and faculty research participation programs in areas that strengthen the Laboratory’s distinctive capabilities and contribute to DOE mission needs

Objective 3.4 Maintain and enhance the Laboratory infrastructure to safely and economically sustain present and future activities

Strategies:
- Optimize the use of available funds for infrastructure maintenance and improvements
- Secure additional resources for modernization and replacement of equipment
- Sustain ORNL's nuclear materials infrastructure and develop a plan for consolidating activities in Melton Valley
- Develop an effective long-range plan for consolidating ORNL activities at the main Laboratory site
- Manage the Oak Ridge Reservation, including the Oak Ridge National Environmental Research Park, to meet the requirements of existing and future scientific facilities, environmental research, education, and other compatible uses

Goal 4. Demonstrate excellence in all aspects of Laboratory management and operations

ORNL will continue to focus on the need for excellence in the management and execution of its work. The objectives associated with this goal describe how ORNL will sustain and improve its ability to serve the needs of DOE and the nation through responsible stewardship of the resources entrusted to its care.

Objective 4.1 Systematically integrate environment, safety, and health (ES&H) into the planning and execution of all research and support activities and continually improve ES&H and quality performance

Strategies:
- Establish and maintain a well-integrated and effective integrated safety management (ISM) program
- Establish and maintain employee training programs to ensure ongoing awareness of the core function and principles of ISM

Objective 4.2 Support the execution of R&D missions with efficient, cost-effective business practices and support services

Strategies:
- Minimize the cost of doing business
- Provide R&D staff with best-in-class support services
- Enhance the safety and efficiency of Laboratory operations
- Maintain and develop the Laboratory's information infrastructure to facilitate the accomplishment of ORNL's strategic goals

Objective 4.3 Contribute to the community as a good neighbor, a resource for knowledge and technology, and a valued employer and partner

Strategies:
- Enhance community outreach and community service programs
- Strengthen public awareness of ORNL and Department of Energy programs, activities, and accomplishments
- Optimize the availability of ORNL's facilities, capabilities, and intellectual property
- Enhance ORNL's contributions to national and regional economic development

- Increase interactions with local and regional businesses
- Expand the availability of educational opportunities that attract talented researchers to ORNL

3.4 • Strategic Directions

In accomplishing the strategies outlined in Sect. 3.3, ORNL will place particular emphasis on several key areas. Of primary importance are the major thrusts through which ORNL will enhance capabilities for leading-edge R&D; these correspond to the major Laboratory initiatives described in Sect. 4. Planned R&D activities that support the strategic goals are described in Sects. 3.4.1–3.4.7.

3.4.1 • 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.

In October 1998, the DOE Nuclear Physics Program established an ISOL Task Force to perform a technical study and evaluation of the options for a next-generation ISOL facility in the United States. The ISOL Task Force Report to NSAC, issued in November 1999, recommends 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 that construction starts in FY 2002, is about $500 million, with operation beginning in FY 2007.

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 during the period before the new facility can be completed. A number of upgrades, with costs ranging from $1 million to $30 million, have been identified. ORNL will work with the Nuclear Physics Program to determine appropriate options for expanding the use of RIBs.

ORNL Physics Division staff members have previously explored the possibility of locating an advanced ISOL facility at the Laboratory. The *ORNL Institutional Plan for FY 1998–FY 2002* (ORNL/PPA-97/2, January 1998) presented a possible layout for such a facility at the HRIBF site. The *ORNL Institutional Plan for FY 1999–FY 2003* (ORNL/PPA-98/2, December 1998) described how an extremely cost-effective RIB facility could be constructed by taking advantage of the very high intensity beam of high-energy protons to be produced in the linear accelerator of the Spallation Neutron Source. Both of these options remain open to consideration if funding is not available to construct the RIA facility proposed by the ISOL Task Force.

3.4.2 • Advanced Materials Characterization

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

For neutron science, this need will be met by the Spallation Neutron Source (SNS) and the upgrades to the High Flux Isotope Reactor (HFIR) and associated neutron scattering facilities (see Sect. 4.1). The need for advanced X-ray characterization tools is being addressed by ORNL beam lines at Argonne National Laboratory's Advanced Photon Source. Investments to meet future needs for electron characterization and related techniques, however, are lagging those in the other areas.

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

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

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

Ideally, this facility will house equipment funded by several DOE offices, primarily 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 Program, funded by DOE-SC—include a strong emphasis on electron-beam characterization and related techniques. The user base for these facilities includes a strong industrial component, as well as international academic users. The management challenge will be to identify funding to construct the facility that builds on the diversity of the programmatic and user support.

Construction of the facility will be guided by the underlying principles of safety, environmental consciousness, and quality engineering, with the necessary environment, safety, health, and quality oversight. The total construction cost for the AMCL will not exceed $27 million. Costs for the initial capital equipment are estimated at $2 million. Design is proposed to begin in FY 2002, with construction to be completed in FY 2004.

3.4.3 • Large-Scale Environmental Process Research

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

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

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

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

ORNL researchers have pioneered advances in methodology and approaches to the study of events that define physical, chemical, or biological change in the environment. They have also established approaches to studying natural ecosystems on a large scale, making use of the extensive resources for long-term environmental process research afforded by the Oak

Ridge Reservation, a substantial portion [≈8,100 hectares (≈20,000 acres)] of which has been designated as the Oak Ridge National Environmental Research Park, a DOE user facility.

ORNL plans to integrate this combination of resources and expertise with its leading-edge capabilities for measurement, modeling, and monitoring of the environment to define and create new approaches to ecosystem process research. Leveraging and enhancing current assets in large-scale ecosystem manipulation, integrated data management, ecological modeling, measurement science and sensor development, and computational science will contribute directly to the ORNL strategic objective of deepening the understanding of environmental processes and systems. This effort directly supports Office of Biological and Environmental Research (OBER) plans, outlined in the Facilities Roadmap Initiative, for integrated user facilities for experimental field research. It also supports DOE goals and objectives in science and technology and addresses the DOE-SC science theme “Protecting Our Living Planet,” with specific application to critical questions about energy by-products and climate change. It also supports the major Laboratory initiative in energy and environmental systems of the future (see Sect. 4.4).

The well-developed DOE and ORNL investments in scientific infrastructure at the Oak Ridge National Environmental Research Park represent a concentration of resources that is unique among U.S. ecological research centers in the United States. The park is home to major large-scale ecosystem manipulation experiments such as a Free Air Carbon Dioxide Enrichment facility; the Throughfall Displacement Experiment, aimed at understanding the impacts of climate change; and lysimeters for study of genetically engineered micro-organisms. The park—particularly the Walker Branch Watershed area—is one of the nation’s most intensively studied sites for understanding biogeochemical cycling in a forested ecosystem. Overall, the National Environmental Research Park provides a combination of heterogeneous and well-characterized geology and hydrology, ecological diversity, fundamental ecosystem process research, modeling, a long-term data record, historical records of land use change, and dynamic pressures on ecosystems resulting from its suburban/industrial setting. The physiography of this ridge and valley setting provides a unique opportunity for several “replicate” catchments on contrasting soil types, further contributing to the value of the site for large-scale experiments.

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

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

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

Preliminary estimates of construction and capital equipment funds needed to develop initial facilities at ORNL are being prepared. Table 3.3 represents a first approximation of projected funding requirements. OBER is the core sponsor of this activity; complementary funding is being sought from programs within DOE's Office of Energy Efficiency and Renewable Energy (DOE-EE) and Office of Environmental Management (DOE-EM) and through new collaborative partnerships with other federal agency sponsors, including the U.S. Forest Service, the Environmental Protection Agency (EPA), the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration, and the Tennessee Valley Authority.

Enhanced university interactions are being fostered through the use of these unique facilities as part of the Oak Ridge National Environmental Research Park user facility. For example, university investigators have secured independent funding from programs such as the DOE National Institute for Global Environmental Change to conduct research in conjunction with the Oak Ridge large-scale environmental process experiments. University and federal agency interactions are also being developed through participation in a university-based multiagency Cooperative Ecosystem Study Unit involving the University of Tennessee, Florida A&M University, the U.S. Forest Service, the U.S. Geological Survey, and the EPA. Current interactions with the DOE-EE Industries of the Future program may be expanded through field demonstration projects related to forest products industry interests in short-rotation woody crops.

Table 3.3
Funding projections for large-scale environmental process research by fiscal year
($ in millions—BA)

	2000	2001	2002	2003	2004
Operating	3.0	3.5	4.0	5.0	8.0
Capital	0.4	0.5	0.5	1.0	0.5
Construction of field experimental facilities	0.0	0.5	5.0	10.0	10.0
Total	**3.4**	**4.5**	**9.5**	**16.0**	**18.5**

3.4.4 • Separations Science and Chemical Processing

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

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

Oak Ridge expertise in separations and chemical processing was initially developed 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, drawing on expertise in solvent extraction, inorganic membranes, adsorption, ion exchange, field-enhanced separations, and dilute solution chemistry. Chemical processing capabilities include analysis of thermophysical properties, computational chemistry, fluid mechanics, pilot-scale operations, process modeling, and life-cycle analysis. Other capabilities include equipment for testing most separations and chemical processes, extensive analytical expertise, and advanced capabilities in process control and monitoring.

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

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

ORNL is capitalizing on its assets and on the interest exhibited by the industry by establishing a focus on separations science and chemical processing. As part of this activity, ORNL is developing a center to coordinate its separations and chemical processing capabilities, establish collaborations with academia, and extend the capabilities to the industrial sector. The Center for Separations and Chemical Processing (CSCP), when fully established, will provide an integrated program and a user center to support the U.S. chemical industry.

The CSCP draws on the capabilities of several ORNL divisions:

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

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

The CSCP 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 the expansion or redirection of a program for measuring the physical properties of hydrocarbons and other materials important to separations in the petroleum and petrochemical industries, a new effort to solve waste problems for DOE-FE, and other activities such as the DOE-EE Industries of the Future initiative.

The CSCP is also establishing a user center for separations and related topics. As a first step, new capabilities and staff are being added to measure chemical and physical properties. This effort also expands ORNL's involvement in related computational research on chemical and physical properties.

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

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

ORNL will take the lead in the CSCP; fruitful cooperation is expected with industries, universities, and other DOE laboratories. Working agreements in separations with leading universities are being developed. A Memorandum of Understanding has been established with the University of Texas, and others are in preparation.

The following actions have been taken during the past year:

- Separations R&D activities, capabilities, equipment, and facilities at ORNL have been cataloged (with support from program development funds).
- Equipment for measuring thermophysical properties has been acquired and installed.
- The Physical Properties Research Facility, which includes the new thermophysical properties measurement equipment, has been established and designated a DOE national user facility.
- Management acceptance of the CSCP concept has been obtained within ORNL and from DOE-SC and DOE-FE.
- ORNL was assigned a leadership role in separations road mapping activities undertaken at DOE headquarters.
- The Laboratory acquired funding for 11 new separations-related proposals, representing a total of $1.5 million from DOE-EE, DOE-FE, DOE-SC, and industry.

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. Projected funding is summarized in Table 3.4. Resources are sought from DOE-SC (Basic Energy Sciences—KC); DOE-EE (Industrial Energy Conservation—ED); and DOE-FE (Petroleum—AC). Support will also be requested from DOE-NE (Nuclear Energy R&D—AF, Isotope Production and Distribution—ST) and DOE-EM (EM30, EM50) and from industry sponsors.

Table 3.4
Funding projections for Separations Science and Chemical Processing by fiscal year
(in millions of dollars)

	1999	2000	2001	2002	2003	2004
DOE						
Office of Fossil Energy	0.50	1.6	2.0	2.0	2.0	2.0
Office of Energy Efficiency and Renewable Energy	0.10	0.4	0.6	1.0	1.5	1.5
Office of Science	0.05	0.2	0.3	0.3	0.4	0.4
Industry	0.20	0.6	1.0	1.5	2.0	2.0
Department of Defense	0.00	0.4	0.6	0.6	0.6	0.6
Total	**0.85**	**3.2**	**4.5**	**5.4**	**6.5**	**6.5**

3.4.5 • Robotics and Intelligent Machines

The DOE complex has been a leader in the basic research, development, and application of robotics and remote systems since the mid-1940s. Many of the laboratories and test facilities used for this work are unique national resources that are critical to the accomplishment of DOE's missions in science and technology, energy resources, environmental quality, and national security. In 1998, DOE Under Secretary Ernest Moniz chartered a multi-disciplinary team to prepare a DOE agency-wide road map for future work on robotics and intelligent machines (RIM). Under Secretary Moniz requested that this team examine RIM as a critical enabling technology, with the objective of developing a crosscutting technology pull strategy for the next 20 years.

Representatives of each DOE Program Secretarial Officer with mission needs requiring RIM worked together to define the principal programmatic needs, which provide the application pull for RIM in the DOE programmatic missions. Technology needs were defined by the key participating laboratories: Sandia National Laboratories, Idaho National Engineering and Environmental Laboratory, and ORNL. The strategic vision of the team was to revolutionize DOE's manufacturing processes, remote handling processes, and monitoring and surveillance processes. Key goals included reducing and/or eliminating DOE worker hazard exposure, improving quality and cost-effectiveness in missions, enabling programmatic missions not presently possible, and improving access to scientific user facilities.

Robotics and Intelligent Machines in the U.S. Department of Energy: A Critical Technology Roadmap (SAND98-2401, Sandia National Laboratories, October 1998) defines an R&D path for RIM from the present through FY 2020. It is expected to serve as the basis for a DOE-wide RIM initiative, beginning in FY 2001.

ORNL is one of DOE's leading performers of fundamental and applied RIM research. Much of the Laboratory's RIM-related work is conducted at the Center for Engineering Systems Advanced Research. ORNL also works with other DOE facilities to develop and apply advanced robotics technology to address needs in energy exploration, environmental restoration, defense, transportation, and other areas. For example, the disposal of unexploded ordnance (see Sect. 6.2.2.2) draws on ORNL capabilities in robotics and remote systems.

ORNL expects to play a continuing role in R&D, demonstration, and application of remote systems, robotics, teleoperation, and related aspects of RIM through interdisciplinary programs for DOE, the Department of Defense, and other sponsors. The Laboratory will also work to expand its fundamental research in RIM and to increase the availability of its RIM-related facilities to support DOE's long-term needs in this critical area.

3.4.6 • Transportation

In 1998, the transportation area accounted for about 28% of the nation's energy use and about two-thirds of its oil consumption. Imports of petroleum ($51 billion in 1998) and of automotive vehicles, engines, and parts ($150 billion in 1998) account for more than 20% of U.S. goods imports, while motor vehicle and equipment manufacturing is the largest U.S. manufacturing industry. In addition, transportation contributes about one-third of the total U.S. 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 transportation research program is the largest and most diversified in the DOE system. Its activities support the needs of DOE, other federal agencies, and industry. For DOE-EE, ORNL conducts R&D on materials, ignition and combustion, alternative fuels, emissions and emission controls, and innovative manufacturing and finishing processes (see Sect. 2.4.4.2). Much of this work supports the Partnership for a New Generation of Vehicles, which focuses the capabilities of DOE national laboratories on the needs of U.S. automobile manufacturers. The ORNL Center for Transportation Analysis conducts R&D on transportation energy and environmental issues, national transportation planning and policy, military transportation and logistics, and transportation systems engineering, focusing on multimodal national and international transportation systems. Customers include the U.S. Department of

Defense, the U.S. Department of Transportation, the U.S. Department of Commerce, the Environmental Protection Agency , and the Bureau of the Census.

Through the Tennessee Transportation Coalition, ORNL and its principal governmental, academic, and industrial partners in the region pursue important opportunities in transportation research. The coalition has played a key role in the development of the National Transportation Research Center (NTRC), a partnership of DOE, ORNL, and the University of Tennessee. The NTRC provides a mechanism for promoting and supporting research activities focused on major transportation R&D issues related to energy, environment, and security for the nation and the world. A research and user facility, now under construction at a location between ORNL and the Knoxville campus of the University of Tennessee, will be the physical home of the NTRC, which is currently operating as a virtual laboratory. Partnerships within the Oak Ridge complex and with other public and private agencies and commercial industry will facilitate transportation R&D.

ORNL possesses extensive resources in hybrid systems, advanced batteries, and fuel cell technologies. These resources will support the development of clean and efficient fuels (see Sect. 4.4). As DOE's lead laboratory for electric vehicle and fuel cell technologies, ORNL will seek broader programs in these and related areas to support the emphasis on clean and efficient fuels, maintain and extend its strengths, and implement technical advances resulting from past and current programs.

3.4.7 • Virtual Human

A human simulation tool, the Virtual Human, is under development at ORNL. The Virtual Human builds on the imagery data from the Visible Human Project sponsored by the National Library of Medicine (NLM), which has as its objective the creation of complete, anatomically detailed, three-dimensional (3-D) representations of male and female human bodies. The goal of the Virtual Human project is to bring these representations to "life" by developing a research, teaching, and applications environment in which complex human responses to biological, chemical, and physical stimuli can be predicted and studied.

The Virtual Human environment will comprise an integrated suite of models of the human body and its functions within an anatomical framework, which can be adjusted to represent different ages, genders, and physiological and psychological states. This problem-solving environment will be able to simulate the body's responses to a variety of input stimuli, including trauma (e.g., from a car crash), exposure to chemicals or radiation, and other "insults."

Requirements include detailed anatomical models, a wide variety of evaluated data (e.g., physiological, biochemical, bioelectrical, and biomechanical), advanced computational algorithms, and a sophisticated user interface that will allow researchers to invoke many types of simulations and obtain results in a variety of formats, including advanced visualizations and numerical data. Terascale computing resources and petabyte storage capabilities will be required to support the computational needs of the Virtual Human.

A number of organizations have expressed interest in human response modeling, but to date there has been little or no coordination of efforts to provide a near-term model of the human. Some of these organizations are working on models for individual organs, while others focus on anatomical models. Work on ergonomics and animation is also under way.

The ORNL approach is distinguished by its focus on combining anatomical structure and physiological function into a single system, with the goal of creating a broad human modeling environment that is accessible through a World Wide Web interface. ORNL is uniquely equipped to lead this task by virtue of its extensive experience with anatomical and biokinetic models, databases, and informatics; its visualization capabilities; its biomedical and engineering experience; and its expertise with the high-performance computing and massive data storage devices required for this computationally intensive project.

A second distinguishing feature is ORNL's decision to create, by 2005, a prototype human modeling system, even though some organ models are functionally rudimentary. The rationale for this decision is that it is more important to the progress of complete human modeling to develop a system with some functionally limited models than to create a partial representation with a very few "perfectly" functional models. This development will create a virtual user facility for the modeling community to test and evaluate methods and algorithms.

Another major objective is to create a capability for responding to stimuli. This implies a third distinguishing feature—the use of an engineering approach (which represents a solid with surface points) rather than voxel models. ORNL is evaluating an approach that permits the generation of finite element models from the Visible Human–derived models (known as "phantoms") and supports animation of the body and organs. This approach also makes it possible to scale the phantoms to represent various ages or individual patient dimensions.

ORNL researchers are presently engaged in the design and implementation of a prototype Virtual Human environment. Once the initial Virtual Human resource is established, DOE, the Department of Defense (DOD), the Department of Health and Human Services (DHHS), and the Department of Transportation (DOT) are expected to be its prime Federal agency users. As modest capability is demonstrated, sizable private sector participation is anticipated.

The technical scope and multidisciplinary nature of this effort present a number of opportunities for teaming and collaboration, and ORNL is actively seeking partners to contribute to the development of the Virtual Human environment. Collaborations have been established with Penn State and Brooks Air Force Research Laboratory and are about to begin with Boston University, East Tennessee State University, the University of Tennessee, and Vanderbilt University.

ORNL is working to establish formal relationships with the Physiome Project at the University of Washington, which is aimed at developing a common approach to organ modeling; the Center for Human Simulation at the University of Colorado, which is building a number of anatomically based organ or body-region simulations from the Visible Human data; and the BioNOME Resource, a Web-based repository of biocomputational models at the San Diego Supercomputer Center. Opportunities for collaboration with private and non-profit R&D entities are also being explored.

Work is also under way to explore DOE contributions to an interagency effort to establish a National Virtual Human Initiative. Such an initiative, bringing together the resources of the national laboratories, universities, and other research institutions, would build on DOE's history of involvement in human health issues and address mission needs for information about the health effects of legacy environmental wastes, future energy technologies, and chemical and biological weapons.

In addition, the Virtual Human has broad applications to the needs of other federal agencies, the medical community, and the private sector. Interest in the Virtual Human has been expressed by the DHHS (through the NLM, the National Cancer Institute, and the

National Institute of Environmental Health Sciences), DOD, the Federal Bureau of Investigation, and the DOT National Highway Traffic Safety Administration.

ORNL is prepared to support DOE in the development of the Virtual Human Initiative. Its resources include its expertise in program management and in such areas as building evaluated databases of neutron cross sections and carbon dioxide data, modeling radiological effects, developing bioinformatics tools, and conducting mammalian genetics research. Key tasks for which ORNL has special capabilities include the following.

- Formulate the architecture of the problem-solving environment, stimulating the development of standards and protocols for models, interfaces, and data. This integrative role will entail the design, implementation, and maintenance of the system.
- Organize and participate in evaluation teams for models and algorithms, working with experts from government agencies, industry, and universities.
- Design the user interfaces and visualization tools for displaying results.
- Lead the Grand Challenge class of computational effort required in information processing and data storage, making use of Laboratory resources in high-end computing and data storage (see Sect. 4.3).
- Identify future research needs to fill data gaps (for example, advanced sensors will be needed to measure, “in vivo,” time-dependent biochemical parameters for hundreds of signaling compounds) and resolve computational implementation issues.
- Facilitate synergism among national and international participants (e.g., other national laboratories, military and research hospitals, international biomedical experts, standards groups such as the International Commission on Radiation Protection).

Uses for the Virtual Human environment cover a wide range. Its ability to address basic science issues and meet data needs should attract traditional science sponsors such as the National Institutes of Health, the Environmental Protection Agency, and the Nuclear Regulatory Commission. Medical applications include modeling of the effects of drugs on different populations, pharmaceutical development, prosthesis development, skeletal and muscular system modeling (of interest in sports medicine), prediction of biophysical effects on brain function, and examination of manifestations of macroscopic injury or trauma at the microscopic level. The National Highway Traffic Safety Administration has expressed interest in the development of scalable finite-element models of the human body for use in simulations of automobile crashes. Military applications have attracted the interest of the DOD Joint Non-Lethal Weapons Directorate, the Defense Advanced Research Projects Agency, and the U.S. Army Soldier System Command.

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, and energy and environmental systems of the future. As described in Sect. 6.2.1, research topics associated with these initiatives have been identified as target areas for Laboratory Directed Research and Development (LDRD) funding.

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

4.1 • Neutron Sciences

Neutrons play a vital role in many areas of science and technology. They provide an ideal probe of the structure and dynamics of condensed matter; they are useful in the study of magnetic structure and dynamics; 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, neutron activation analysis, isotope production, and material irradiation testing. Research at ORELA now concentrates on nuclear astrophysics and basic neutron properties (e.g., neutron electric polarizability); ORELA is available for other applications, such as target experiments for the proposed Spallation Neutron Source (SNS), and as a positron beam facility. Measurements made on ORELA also support DOE's Nuclear Criticality Safety Program.

In addition to neutron sources, facilities supporting ORNL's broad neutron science programs include the Radiochemical Engineering Development Center, the Radioisotope Development Laboratory, the Transuranium Research Laboratory, and the Irradiated Fuels

Examination Laboratory. The calutrons of the Isotope Enrichment Facility are available to separate stable isotopes and can also make feedstock for radioisotope production. 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 major initiative to ensure that the Laboratory continues its stewardship of neutron science in support of DOE's science and technology missions. This initiative incorporates the following activities:

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

4.1.1 • Spallation Neutron Source

The Spallation Neutron Source (SNS) is an accelerator-based, next-generation neutron scattering facility scheduled to be built on the Oak Ridge Reservation. It will produce neutron beams that are 6 to 10 times more intense than any existing pulsed source, enabling researchers to "see" never-before-observed details of physical and biological materials, ranging from high-temperature superconductors to proteins. The SNS is the top-priority project of DOE's Office of Science (DOE-SC), which has committed approximately $169 million through FY 1999 for its design and preparation. It will support DOE's strategic goal in science and technology by significantly improving the nation's capability for conducting high-quality, innovative research.

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

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

DOE-SC. The review committee consisted of 65 scientists, engineers, and business leaders from the United States and Europe. The committee strongly endorsed the SNS Collaboration, its reference design, technical scope, cost, schedule, and collaborative management approach.

In FY 1998, DOE-SC provided $23 million to prepare for a construction start in FY 1999. Following a second major readiness review in June 1998, DOE-SC concluded that the SNS team was ready to initiate Title 1 design and construction activities. An architect-engineering/construction management (AE/CM) firm was selected to assist the SNS in these activities, which began in October 1998. The Energy and Water Appropriations Act for FY 1999 included $130 million and a construction line item for the SNS in FY 1999.

An SNS Neutron Instrumentation Workshop and Oak Ridge Neutron Users Meeting was held in November 1998 and attracted more than 220 participants. This diverse group of neutron scientists represented many different disciplines in which neutron scattering techniques are used to study structure and dynamics in materials. The Instrumentation Workshop focused on

- the status and expected performance of the SNS,
- priorities for the initial suite of 10 instruments to be built at the high-power target station as part of the SNS reference design, and
- the science case for a second target/instrument suite optimized for long-wavelength neutrons.

The final environmental impact statement (DOE/EIS-0247) analyzing the proposed ORNL site and alternative sites for the SNS was completed in April 1999. A Record of Decision, which identifies Oak Ridge as the preferred site for the SNS, was issued in June 1999. Groundbreaking ceremonies for the SNS were held in December 1999.

The FY 2000 Energy and Water Development Appropriations Act, P.L. 106-60, includes $117.9 million for the SNS ($100 million for construction and $17.9 million for design R&D). Table 4.1 presents the SNS funding profile to date.

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

1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Total
8	8	23	130	117.9	TBD[a]	TBD	TBD	TBD	TBD	1,363

[a]To be determined.

4.1.2 • High Flux Isotope Reactor Upgrade

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

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

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

The complete HFIR upgrade package would

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

The DOE-SC Office of Basic Energy Sciences has identified program funds to complete the new cold neutron source, install it in the HB-4 beam line on the HFIR, and make the necessary modifications to the HFIR to support the thermal neutron beam guides. Coupled with the steady upgrading of instrumentation over the last few years, these changes will make the HFIR the most intense source in the world for thermal neutron research and will make its cold neutron source capabilities competitive with the world’s best.

The capabilities resulting from the addition of the cold neutron source will support world-class fundamental and applied research programs and could provide the key to new discoveries and applications for plastics, alloys, and biochemical systems. As a complement to the capabilities of the SNS, they will address important needs of the neutron scattering research community. It is expected that the cold source will be installed in FY 2001 during the routine replacement of the HFIR reflector.

The thermal neutron scattering upgrade, to be completed in FY 2001, will include enlarged beam tubes, new monochromator drums, and extension of the HB-2 beam line into the existing HFIR beam hall using neutron guides. The HB-2 extension will provide space for existing neutron scattering instruments displaced by the cold neutron source. Neutron guides work like fiber-optic guides—they are rectangular conduits whose inside surfaces are coated with one or more layers of material, which reflect neutrons that strike the surface at a glancing angle, if they are not traveling too fast. Thus, the guides can bring neutrons from close to the reactor, in a series of ricochets, to an instrument more than 30 m (100 ft) away, with little loss. A large thermal neutron guide hall, into which these beam guides could be extended to as many as 15 spectrometers, has been proposed. This hall would provide more space for instruments in a low-background area outside the reactor building. It would also increase the number of users that could be accommodated by increasing the number of beams and instruments. Office and laboratory space would be provided in the new hall for outside users and for ORNL researchers.

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

Completion of the thermal neutron (HB-2) guide hall will require approximately $25 million ($1.0 million in FY 2001, $15 million in FY 2002, and $9 million in FY 2003). Other upgrade activities either are already funded or will not begin until after the current planning period.

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

4.1.3 • Joint Institute for Neutron Sciences

The Joint Institute for Neutron Sciences (JINS) was established in February 1998 to serve as both an intellectual focus for neutron science and the gateway for the guest scientists and engineers expected to use the SNS and the upgraded HFIR, which will provide, respectively, the most intense pulsed and steady-state neutron beams available anywhere. JINS is operated jointly by ORNL and the University of Tennessee, and a director is currently being sought. The combination of these neutron science capabilities and the presence of JINS will enhance Oak Ridge's position as a leading center for neutron scattering research.

JINS will provide services to users of the ORNL neutron science facilities in a building funded by the State of Tennessee and constructed on ORNL land situated between the SNS and the HFIR. The State of Tennessee, through the University of Tennessee, has committed $8 million for construction of a facility to house JINS. No additional funding from DOE will be required. The facility is expected to provide accommodations for visiting researchers, dining facilities, meeting space, and other services.

The Oak Ridge Neutron Users Meeting in November 1998, held in conjunction with the SNS Neutron Instrumentation Workshop, attracted more than 220 participants representing many different disciplines in which neutrons are used to study structure and dynamics in materials. At this meeting, the SNS and HFIR Users Group (SHUG) was formed, and bylaws and a charter for the group were adopted. The purpose of the SHUG, as stated in the charter, is to

- provide a formal and clear channel for the exchange of information and advice between the investigators who perform neutron scattering and neutron science experiments at ORNL and the management of the SNS, the HFIR, and the JINS;
- serve as an advocacy group for the neutron scattering and neutron science activities at the SNS and the HFIR; and
- provide a communication channel among users of the SNS and the HFIR.

4.2 • Complex Biological Systems

Biological research has been transformed by recent advances in molecular biology, bioanalytical technologies, and computational science and by large-scale programmatic initiatives, such as the Human Genome Project, that catalyze the efforts of research teams whose work crosses traditional disciplinary boundaries. As information becomes available from the human and other genomes, as well as from high-throughput biomolecular structure determination, a greater challenge is emerging: understanding complete biological systems, from the molecular level to the level of the functioning organism.

New capabilities will be necessary to investigate and understand the complex interactions, pathways, balances, and control mechanisms of the many components of biological systems. ORNL will contribute to the development of these capabilities by bringing together its established programs and expertise in the life sciences; its strengths in the innovative application of computational, physical, chemical, and engineering sciences to biology; and its special facilities and resources in analytical technologies in a new complex biological systems initiative.

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

Key areas to be pursued through the complex biological systems initiative include the following.

- Promotion of a comparative systems biology that leads to better use and integration of information from different model organisms. Experimental and computational methods are needed to produce, exploit, and integrate information from several organisms to explain and understand complex but shared pathways. Different organisms have unique strengths and weaknesses for studies of different aspects of complex but evolutionarily conserved pathways and systems; exploiting existing but unconnected information and the unique benefits of different organisms should lead to new understanding and opportunities for research.
- Definition and development of good model "complex pathways" or specific biological processes, in any organism, that can serve as unique and tractable systems for future dissection and study.
- In vitro and whole-organism approaches for complex pathway analysis.
- Initial identification and precise definition of some of the components of selected complex pathways that can then be effectively analyzed by new technologies. This includes defining in complex functions that may serve as monitors of that function or pathway in vivo.
- Genetic and molecular approaches to identifying gene-product interactions in networks as well as temporal changes in the functional roles of specific gene products.
- Integrated genomic approaches to analyze complicated signaling pathways, regulatory networks, and the relationships between organisms and environments.
- Analytical technologies that provide simultaneous information on multiple biological processes, are scalable for high-throughput analysis, and are easily adapted for investigation of different processes using a variety of organisms and molecular systems.
- Analytical technologies that can provide analysis at the single-cell level, including technologies that provide spatial and temporal information either in real time or as accurate snapshots.

- Mathematical modeling of checks and balances in known pathways, such as the balance of protease and protease inhibitors in tissue remodeling.

The complex biological systems initiative builds on ORNL's previous major initiative in functional genomics and proteomics, through which the Laboratory has developed a strong program in this key area (see Sect. 4.2.1). It also incorporates programs in 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 Biological Sciences (see Sect. 4.2.5), which is under development with support from DOE-SC's Office of Biological and Environmental Research (OBER), and the ORNL–University of Tennessee Joint Institute for Biological Sciences (see Sect. 4.2.6). Funding projections for the complex biological systems initiative are shown in Table 4.2. (These projections do not include capital funding for the Center for Biological Sciences, which are presented in Sect. 4.2.5.)

Table 4.2
Funding projections for complex biological systems initiative by fiscal year
(in millions of dollars)

	2001	2002	2003	2004
Functional genomics and proteomics	6.0	8.0	10.0	10.0
Center for Structural Molecular Biology	1.1	2.0	2.5	3.0
Plant and microbial genomics	2.0	2.5	3.0	4.0
Computational biology and bioinformatics	3.0	3.5	4.0	4.0
Total	12.1	16.0	19.5	21.0

4.2.1 • Functional Genomics and Proteomics

The Human Genome Project is expected to produce a "working draft" of the reference human genome by summer 2000, providing the biomedical research community with a computerized catalog of the names, locations, and nucleotide sequences of the more than 80,000 genes on the human chromosomes. Significant advances in the ability to determine the function of genes, within and across genomes, will be needed to unlock the information contained in the output from sequencing and gene searches.

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 from the genome program is changing this situation. In the new era of biomedical research that has just begun, it will be possible to perform experiments in functional genomics—that is, to determine the function of genes and systems of genes on a genome-wide scale.

Gene function is determined (1) by analyzing the effects of DNA mutations in genes on normal development and health in the whole organism; (2) by analyzing a variety of signals encoded in the DNA sequence; and (3) by studying the proteins produced by a gene or system of related genes. Researchers 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 forthcoming availability of complete DNA sequences for many organisms will also enable whole 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 and other agencies, drawing on new high-throughput assays to determine the structures of proteins and on studies of 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. The focused investment of Laboratory Directed R&D (LDRD) funds in this program from FY 1997 through FY 1999 has served to catalyze cross-disciplinary research projects, involving biologists, chemists, engineers, physicists, and computer scientists, to develop the tools required for mounting a highly efficient, comprehensive system for functional genomics and proteomics.

New approaches are being applied to the task of enriching raw DNA sequences, generated at the DOE Joint Genome Institute (JGI) and elsewhere, with functional information derived from gene expression and protein studies of mutations in the mouse. Researchers are combining advanced methods in mouse mutagenesis with the development of new functional genomics and proteomics technologies, both analytical and computational, to understand how gene expression affects specific biological systems. These technologies are also being used to study important bacterial and plant systems (see Sect. 4.2.3).

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

ORNL is melding its advanced technologies and computational biology capabilities with its mouse mutation resources to establish highly efficient techniques for defining specific functions of proteins in mutation models. Work is under way along the following lines:

- Gene expression and protein analysis techniques for augmenting primary phenotype screening and secondary/tertiary analyses of mutant phenotypes. Automated, high-throughput phenotype screening techniques are under development.
- Technologies to facilitate genetic linkage analyses in large-scale mouse crosses for genetic dissection of complex biological pathways. ORNL will apply its established methods in mass spectrometry (based on matrix-assisted laser desorption techniques) to support high-throughput linkage analyses. Complementary technologies, including novel hybridization chips and microfluidic devices, are also being developed.
- In vitro and whole-animal approaches for complex pathway analysis. Researchers are investigating a new means for in vitro screening for recessive mutations. Chip-based mRNA expression profiling technologies (which can screen for expression of genes involved in cellular processes, such as apoptosis) will be incorporated.
- New techniques for high-throughput detection of variants of specific proteins that can then be used in both genetic (organismal) and structural (biophysical) analyses. ORNL will develop high-throughput mass spectrometry–based procedures for carrying out one-generation chemical mutagenesis screens. Results from these “protein variant screens” will then direct the matings of variant mice to reveal both dominant and recessive whole-organism, functional phenotypes.
- Structural characterization of mutant proteins with phenotypic ramifications and comparison with wild type for determination of structure/function relationship. Resources in mass spectrometry and a new facility for small-angle neutron scattering that is part of the proposed Center for Structural Molecular Biology (see Sect. 4.2.2) will be combined with structural techniques, including synchrotron-based protein crystallography and NMR, available at collaborating national laboratories and with ORNL’s expertise in computational biology (see Sect. 4.2.4).
- Validating predictions of protein structure and function through mouse genetics and mutagenesis. As more genomic DNA sequence data become available from the JGI and other sequencing centers, mouse genetics and mutagenesis, combined with computational analysis, will become a powerful tool for understanding gene and protein function at a number of levels.

As with all actively growing research programs, new directions will become apparent and drive changes in direction; the activities listed here provide an overview of the program and the kinds of information to be obtained.

In summary, the goal of the ORNL Functional Genomics and Proteomics Program is to understand protein function in the context of the whole animal 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 institutions, particularly other national laboratories, ORNL will ensure complementarity with related programs in functional genomics and proteomics and will make its resources and technologies available to them.

ORNL will also 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, established in December 1998, is supporting expanded collaborations with Meharry Medical College, St. Jude Children's Research Hospital, the University of Tennessee Medical Centers at Knoxville and Memphis, and Vanderbilt University Medical Center. An April 1998 conference, "Partnering for Functional Genomics Research," attracted representatives from 14 pharmaceutical and biotechnology companies, all of which expressed interest in further interactions. 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. Follow-on activities are under way to establish collaborative efforts and to pursue the development of an R&D consortium involving several industry partners.

4.2.2 • Structural Biology

Structural biology is a rapidly growing field with a burgeoning impact on basic and applied biology. ORNL proposes to combine its strengths in neutron sciences, mass spectrometry, and computational biology and make them available to a broad user community in the biological sciences by establishing a Center for Structural Molecular Biology (CSMB). The CSMB will be a key component of the proposed Center for Biological Sciences (see Sect. 4.2.5).

The cornerstone of the CSMB is a small-angle neutron scattering (SANS) facility to be constructed at the High Flux Isotope Reactor (HFIR) at ORNL. 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 also provides information on the dynamics of a biomolecule in solution and complements high-resolution structural X-ray crystallographic data obtained from static, crystalline molecules. SANS will be a key tool for understanding the cellular-level communication that is the basis for protein function and, thus, gene function.

Establishing the CSMB at this time is particularly advantageous because 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. This instrument 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 (ILL) in France.

The CSMB will also leverage 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 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 proposed 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 has been established to provide guidance to the director and staff of the CSMB in the establishment of the center. A CSMB User Group, consisting of potential users of the center, will be 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.

SANS facilities at the HFIR will be specifically designed for high flux and 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;
- a small-angle X-ray scattering instrument that can be used to evaluate biological samples before SANS experiments;
- resources in biological mass spectrometry, including two 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 (see Sect. 4.1.3).

In the longer term, the capabilities afforded by the Spallation Neutron Source (see Sect. 4.1) will create new opportunities in structural biology. The proposed Center for Biological Sciences (see Sect. 4.2.5) will serve as the point of coordination for future CSMB activities that draw on these capabilities.

The proposed 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

In parallel with the Human Genome Project, intensive efforts are under way to sequence the genomes of plants, with obvious implications for agricultural crops, and of important pathogenic and environmentally and commercially significant microorganisms. Several smaller genomes have been completely sequenced, providing a wealth of new genetic information. The availability of this information and the development of new tools (e.g., sequencers and robotic systems) that allow for the gathering of genetic 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 Nonproliferation and National Security (DOE-NN), and the DOE Office of Environmental Management, build on the Laboratory's long-term involvement in environmental monitoring and bacterial isolations. Work in environmental monitoring expanded to include biosensors, now a key area of expertise. Efforts in bacterial isolations identified unique bacteria that represent resources for future projects and fostered the development of molecular expertise that supports new efforts in microbial genomics. Investment of capital resources in equipment for molecular-level explorations also supported the development of expertise and set the stage for future projects and expansion into related areas.

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 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, under the sponsorship of DOE-SC and the DOE Office of Energy Efficiency and Renewable Energy, the complexity of the interactions among metabolic pathways and between integrative gene expression and the environment currently limits the 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. These areas will be developed and explored at ORNL, drawing on the availability of new equipment (e.g., a new DNA sequencer) in the development of new abilities.

New tools and approaches in bioinformatics will be needed to deal with new DNA array data and DNA sequence data. Work at ORNL to develop artificial neural networks for pattern recognition is laying the groundwork for processing some of these data. 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

In 1991, Eric Lander, a pioneer in human genome research, remarked, "Biology is in the middle of a major paradigm shift—driven by computing. Although it is already an informational science in many respects, the field is rapidly becoming much more computational and analytical."[1] Today it is fair to say that many large multinational biology research programs—such as the Human Genome Project, other genome sequencing efforts, and emerging proteomics and systems biology programs—simply would not succeed without major investments in computational biology/bioinformatics research and computational infrastructure.

ORNL has a significant program, dating from the early 1980s, in bioinformatics and computational biology. Early successes include GRAIL™ (Gene Recognition and Analysis Internet Link), a gene finding and modeling tool that applies advanced pattern recognition technology and has become a widely recognized standard in gene finding and modeling. The latest development, GRAIL™-EXP, is unparalleled in its ability to accurately find genes in long segments of double-stranded genomic DNA, a capability that is critically important for the analysis of the output of large-scale sequencing.

These and other informatics tools developed at ORNL and elsewhere have been integrated into a high-throughput analysis sequence analysis pipeline, the Genome Channel. This tool examines a DNA sequence and then predicts genome features, including gene models and the resulting protein models. The predicted protein models are compared to databases of existing proteins for similarities in protein sequence; this adds biological meaning to the genome sequence by suggesting the biological function of the genes and proteins encoded by that sequence. The information is regularly recomputed and updated as new data become available. A major milestone was recently reached when 10% of the human genome (305 million base pairs, i.e., the entire amount of sequenced reference human DNA to date) was completely analyzed and made accessible in the Genome Channel. Thousands of additional gene and protein models that have not been seen before were discovered in the sequence. The user interfaces for the Genome Channel and the associated Genome Catalog include information about the sequence, the sequence assemblies, predicted genome features, and links from genes and their relatives in other organisms.

Rapidly characterizing the protein models resulting from genomic sequences includes classification of putative proteins into functional classes, based on sequence information, as well as folding prediction. A new computer-based system for protein tertiary fold prediction, developed by the ORNL team, predicts the approximate tertiary structure of a protein sequence based on the recognition of structures or partial structures in a large database of known protein folds. The system is unique in guaranteeing to find a globally optimal alignment and doing so very efficiently (with polynomial-time efficiency). This represents a new breakthrough in the area of fold recognition–based protein structure prediction methods.

The ORNL method scored among the top 5% of approaches that competed in CASP3, the Critical Assessment of Structure Prediction competition involving more than 100 groups worldwide. The most recent predicted structure, an *E. coli* pyrophosphokinase, was well matched to the recently completed crystallographic structure. Research groups at institutions such as the National Institutes of Health, Lawrence Berkeley National Laboratory, Amgen, and Boston University have expressed interest in using the system in their research and in collaborative developments related to this project.

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[1] E. S. Lander, *Computer* **24** (11), 6–13 (1991).

The computational biology and bioinformatics effort takes advantage of ORNL's high-performance computing environment (see Sect. 4.3). As sequence data rates increase rapidly to unprecedented levels, and as the throughput of the analysis pipeline and computational characterization of proteins keep pace with the sequencing, a high-performance computing infrastructure becomes even more critical to the success of this effort. Development of the Center for Biological Sciences (see Sect. 4.2.5) will also improve the linkages between the computational biology and informatics program and the other elements of the Complex Biological Systems initiative.

4.2.5 • Center for Biological Sciences

OBER is planning for a significant investment in a new Center for Biological Sciences (CBS) at ORNL during the FY 2001–FY 2004 period. The CBS is planned as a modular complex of buildings, equipment, and infrastructure to house current and future research programs in functional genomics, structural biology, proteomics, and systems biology. It will provide the environment for the ORNL biological research program to make significant contributions to biology during the next decade and beyond, with a special focus on complex biological systems research. Development of the CBS will enhance the advantages gained from the program's recent restructuring to embrace not only the biological sciences but also allied disciplines in information science and computing, analytical methodologies, and chemistry. Table 4.3 provides funding projections for the CBS.

The initial element of the CBS is the new Environmental and Life Sciences Laboratory, now being constructed with General Plant Project (GPP) funds. The next phase in the development of the CBS is the construction of a Laboratory for Comparative and Functional Genomics (LCFG), at an estimated cost of $14 million, to house the Mouse Genetics Research Facility. The LCFG will replace an aging building at the Oak Ridge Y-12 Plant that is no longer adequate to house one of ORNL's premier research facilities. In addition to the mouse colony, the LCFG will include laboratories with special phenotype screening and cryopreservation capabilities, thus supporting the ORNL Functional Genomics and Proteomics Program (see Sect. 4.2.1).

The CBS will also encompass the proposed CSMB (see Sect. 4.2.2). The Spallation Neutron Source beam line identified in Table 4.3 is the principal new capital resource needed to support the CSMB beyond 2003.

Table 4.3
Capital funding projections for the ORNL Center for Biological Sciences by fiscal year
(in millions of dollars)

	2001	2002	2003	2004
Laboratory for Comparative and Functional Genomics	2.5	10.0	1.4	0.0
Structural biology beam line for the Spallation Neutron Source	0.0	0.0	3.0	3.0
Computational biology and bioinformatics	2.0	3.0	0.0	0.0
Proteomics	3.0	5.0	2.0	0.0
Instrumentation	2.0	1.0	1.0	1.0
Total	9.5	19.0	7.4	4.0

ORNL's resources in bioinformatics and computational biology (see Sect. 4.2.4) will be enhanced by and contribute to the CBS, which will provide space and "connectivity" (computing and information technology infrastructure) for both the bioinformatics and computational biology researchers and the experimental biologists. The leverage gained through this combination of expertise and infrastructure will also provide tools facilitating the use of the CBS facilities as a virtual laboratory by research partners at other institutions.

Research programs at the CBS will encompass ORNL's important efforts in protein biochemistry, which were recognized in 1998 with the election of a senior staff member to the National Academy of Sciences. The CBS will provide the physical environment for fully integrating these efforts into ORNL's biological research program and bringing them to bear them on the broader charge of proteomics.

Future biological research at ORNL will be aggressively directed to take advantage of advances not only in computational biology but also in instrumentation and measurement sciences and technology. Facilities at the CBS will co-locate bioinstrumentation and bio-engineering R&D efforts with the new biological research programs. These programs will build strong alliances with other biological and medical research centers, building on the resources of the Joint Institute for Biological Sciences (see Sect. 4.2.6).

4.2.6 • Joint Institute for Biological Sciences

ORNL and the University of Tennessee (UT) have established the Joint Institute for Biological Sciences to promote and develop support for collaborative education and research in biological sciences. UT organizations involved in this effort include the Medical Center, the College of Veterinary Medicine, and the Institute of Agriculture.

The initial phase focuses on strengthening the partnership between ORNL and UT and developing or expanding collaborative efforts in functional genomics, structural biology, and computational biology and bioinformatics. This phase includes the integration of the ORNL-UT Graduate Program for Genome Science and Technology into the Joint Institute. The second phase in the evolution of the Joint Institute will explore new areas such as forensic sciences, biomimetics and biomaterials, and biomedical technologies.

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

4.3 • Terascale Computing and Simulation Science

4.3.1 • New Directions in Computation and Simulation

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

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

ORNL has played a leading role in these advances. The Laboratory has been at the forefront in acquiring and evaluating massively parallel computers and bringing them to production status. The worldwide popularity of distributed computing can be traced in large part to ORNL's development of the PVM (Parallel Virtual Machine) software for efficiently linking computers into networks. ORNL has also contributed to advances in parallel code development, in data storage systems and software, and in visualization and networking. The linking of the Intel Paragon computers at ORNL and Sandia National Laboratories to solve formidable computational problems represents success in addressing a range of challenges in wide-area metacomputing. ORNL's work on the Electronic Notebook, the Collaborative Management Environment, and the Materials Microcharacterization Collaboratory has contributed to more effective collaborations and more efficient use of DOE resources.

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

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

4.3.2 • ORNL Resources and Opportunities

As DOE's most programmatically diverse national laboratory, ORNL conducts a broad range of theoretical and experimental programs (see Sect. 2.4.4). ORNL is also home to a comprehensive computational science effort that leverages extensive expertise in the application of computing to physical problems and excellent facilities for massively parallel high-performance computing to answer scientific questions and to advance the development of computational resources.

- The Computer Science and Mathematics Division (CSMD) is the focal point for the development and application of innovative computational systems and tools. Resources include a 400-gigaflops IBM SP supercomputer (slated to be upgraded to a 1-teraflops machine by March 2000), a 300-terabyte data storage and access system, extensive efforts in parallel code development and in strategies for wide-area metacomputing, and a broad range of visualization and networking systems and expertise. CSMD is a world leader in basic research on heterogeneous distributed computing, applied mathematics, and collaborative technologies. CSMD also carries out basic research in quantum computing, cooperating autonomous systems, and nonlinear science. Ongoing applied research projects include computational materials science, global climate simulations, combustion modeling, transportation, genomics, and computational neurosciences.
- The Computational Physics and Engineering Division (CPED) offers capabilities in computational physics, computational engineering, integrated computing applications, and nuclear engineering computations and analysis. CPED has a 30-year history of applying computers to physical science problems relating to energy, the environment, and health and safety research.
- The Computing, Information, and Networking Division conducts R&D on high-speed interconnect technology and Next-Generation Internet capabilities for handling distributed computation, control, and collaborative applications for government and industry.

Additional expertise is distributed throughout ORNL. For example, the Chemical and Analytical Sciences Division is exploring computational chemistry and nanotechnology; the Energy and Environmental Sciences divisions are working with CPED and CSMD on climate modeling; the Fusion Energy Division uses high-end computing to address transport phenomena, plasma behavior, heating and current drive, and plasma edge effects in fusion experiments; the Life Sciences Division carries out pacesetting efforts in computational biology and development of computational tools for analyzing the structure and function of genomes, genes, and proteins (see Sect. 4.2.4); the Metals and Ceramics Division is performing large-scale simulations of materials properties, using a hierarchy of increasingly accurate and computationally intensive techniques; and the Physics Division is engaged in computational nuclear structure and computational astrophysics.

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

4.3.2.1 • Applications

Climate Prediction

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

Working with the Argonne National Laboratory and the National Center for Atmospheric Research (NCAR), ORNL has advanced the use of massively parallel computers for climate modeling through the development of numerical methods and parallel algorithms and the implementation of the NCAR Community Climate Model (CCM) on the IBM RS/6000 SP and the SGI Origin 2000. Work to develop new climate models that can take advantage of new levels of supercomputing power continues through DOE's Climate Change Prediction Program.

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

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

Combustion

Internal combustion engines have been identified as the source of one-third of the world's pollution and ozone-depleting greenhouse gases. Emerging demands for emission reduction will require the development of dramatically cleaner and more efficient combustion technologies. Detailed computational models can improve the understanding of combustion, leading to innovative designs that achieve lean fuel limits, low emissions, and high efficiency.

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

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

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

Materials

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

- Accurate simulation of the properties of materials whose behavior depends on the electronic structure of systems comprising hundreds to thousands of atoms; until recently, such investigations were considered untenable because of the large number of particles necessary for accurate simulations.
- First-principles calculations of variations of electrical resistivity in layered magnetic alloys, which offer the promise of 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.

Genomics

ORNL's strong and rapidly growing computational biology and bioinformatics effort is an integral element of the complex biological systems initiative described in Sect. 4.2. The focus is on extending the range of understanding of biological phenomena from molecules to systems to phenotype and organism function. This understanding is critical to DOE's science and environmental missions.

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

Fusion Energy Sciences

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

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

Biomedical Engineering and Physics

As described in Sect. 3.4.7, ORNL is supporting an effort by DOE, in collaboration with other government agencies, to develop a National Virtual Human Initiative to produce a computationally based environment that condenses and organizes existing information on human anatomy, physiology, genetics, toxicology, and disease. Modeling of human systems and subsystems in an integral fashion will help to extract the full implications of this information in terms of human responses to external and internal stimuli. Computational challenges for this environment include the massive amounts of data and dynamic modeling over a wide spectrum of spatial and temporal scales with highly visual input and output at remote locations. The ORNL prototype Virtual Human environment, which is supported by LDRD funding, and other projects related to biomedical engineering and physics will require the highest level of computer resources, visualization capability, and collaborative and distributed computational environments.

4.3.2.2 • Resource Development

As the development of more powerful supercomputers continues, advances in processing power must be complemented by advances in computing, communications, and information tools and technologies. For example, a balanced 5-teraflops system requires 2 terabytes of computer memory, 5 petabytes (5×10^{15} bytes) of data storage capacity, and input-output (I/O) capacity exceeding 200 gigabits per second. In addition, operating systems, I/O software, communications software and protocols, visualization systems, data management systems, and network interfaces must all work together with application codes and hardware. Seamless access, secure networks, readily accessible data storage systems, and software and applications must be provided to support user needs.

Hardware

ORNL has demonstrated an outstanding ability to bring large prototype parallel computers to production performance and innovative use, producing results that support DOE missions in science and national security. The Laboratory is now moving ahead to the task of bringing new terascale systems to effective performance through several different activities.

- ORNL has acquired and installed a 400-gigaflops IBM SP system, to be upgraded to 1 teraflops in March 2000.
- ORNL is conducting a comprehensive evaluation of the SRC-6, an innovative shared-memory machine being developed by SRC Computers, Inc.
- ORNL has acquired a Compaq AlphaServer, currently installed with 64-gigaflops performance capability, with options to upgrade this system to a terascale system in support of the SSI or other DOE computing initiatives.

Networking

Networking is both the infrastructure that ties all other elements of computing together and an area of active research in and of itself. ORNL has a long history in networking, dating from its early connection to MILNET and from its role as one of the five original sites on what became known as MFEnet (the Magnetic Fusion Energy Network), which evolved into ESnet (the Energy Sciences Network). ORNL continued as a main hub on this network and was one of the first sites to migrate to ESnet2, as the second-generation network was called when it switched to asynchronous transfer mode (ATM) technology in 1994. This network served as the basis for groundbreaking experiments in a 1995–97 collaboration between ORNL and Sandia National Laboratories. Researchers conducted multiple-machine linked runs of combustion, climate, and materials codes in one of the first demonstrations of genuine distributed high-performance computing. The two supercomputers at ORNL and Sandia filled and fully used the ATM OC3 connection that linked them. Accomplishments included modifying PVM to handle firewall tunneling for connections between DOE-SC and DOE Office of Defense Programs laboratories, the first low-level ATM cross-country run, and a 1996 R&D 100 award for participation in the development and testing of the GigaNet OC12 interface. ORNL has also been at the forefront of remote operation of laboratory instruments and collaborative technologies through projects such as the Materials Microcharacterization Collaboratory, which gives researchers remote access to scanning tunneling microscopes via a Web-based interface.

ORNL’s network research group has been a leader in developing protocols for supporting mobile computing, improving network security, and parallel routing. In addition, ORNL is a silent partner in the Ultrafast Optical Communications Consortium in Atlanta, which links BellSouth, Corning, Nortel Networks, and the Georgia Institute of Technology. The consortium is developing techniques to enhance fiber-optic technology by extending the present-day capacity per wavelength from 10 gigabits per second (Gbps) to 80–90 Gbps.

Computer Science and Enabling Technology

ORNL has led the development of several enabling technologies for computer science that have become worldwide *de facto* standards. The PVM software package is used for distributed computing at thousands of sites. The LAPACK and ScaLAPACK packages for high-performance linear algebra are heavily used in commercial and research software. The

QMRPACK package and several sparse matrix solvers developed at ORNL are used in a variety of scientific and engineering applications, ranging from first-principles electronic structure codes for Grand Challenge problems in materials science to codes used in the automotive and aerospace industries.

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

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

4.3.3 • ORNL Plans

The DOE-SC theme "Extraordinary Tools for Extraordinary Science" recognizes the importance of mathematical and computational tools in predicting the behavior of complex systems and conducting multidisciplinary research. ORNL expects to build on its present role in developing and applying these tools.

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

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

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

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

1. Upgrade the IBM SP supercomputer to 400 gigaflops (estimated time to completion: 1 month).
2. Plan and prepare for a terascale machine at ORNL to replace the Intel Paragon computers (estimated time to completion: 6 months).
3. Develop a prototype regional climate center to support climate research studies in the southeastern United States (estimated time to completion: 6 months).
4. Develop one or more simulation centers with significant computational resources for collaborative applications (estimated time to completion: 18 months).
5. Develop significantly more expertise in simulation and modeling, through mechanisms such as encouraging cross-divisional collaborations that make use of simulation centers (estimated time to completion: 18 months).
6. Plan and install advanced networking facilities to increase the internal connectivity at ORNL and to provide a higher level of connectivity with other DOE laboratories and collaborating institutions (estimated time to completion: 24 months).

Several avenues are being taken in preparation for the acquisition and installation of a world-class terascale supercomputer. One strategy for achieving terascale capabilities, now being implemented, is the accelerated upgrade path for the IBM SP supercomputer. Evaluation of the SP system and its upgrade options is under way. A second path toward the goal of a terascale system is provided by the new Compaq parallel computer. ORNL has also contacted SGI about the possibility of obtaining the initial model (serial number 1) of the SGI SN-1 supercomputing system.

ORNL will perform an early system evaluation of the SRC-6 multiprocessor system. DOE-SC is funding the purchase of two SRC-6 units, to be combined in a 25-gigaflops system. ORNL will assess the performance of this system on Grand Challenge–level codes in such areas as materials science, computational fluid dynamics, and global climate change modeling. ORNL will work with the national energy research community to develop specifications for an appropriate terascale system.

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

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

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

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

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, ORNL's connection to other DOE laboratories (and to the greater Internet) will increase from OC3 (155-Mbps) to OC12 (622-Mbps) bandwidth. 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.

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

4.4 • Energy and Environmental Systems of the Future

ORNL proposes to develop 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 45% of the petroleum products that it consumes. Moreover, the production and use of energy from fossil fuels are major sources of environmental damage.

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 energy resources in response to this rapid growth runs counter to the concept of "sustainable development"—development that meets the needs of today without compromising the ability of future generations to meet their own needs.

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 50 years to meet global needs for energy services and eliminate inequities between more and less developed nations.

It is also increasingly clear that the resources and technology systems meeting a very large proportion of current needs are not sustainable. Not only are fossil fuel sources, especially 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 and weather 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—requires the identification of 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. The National Academy of Sciences/ National Research Council Board on Sustainable Development identifies this "sustainability transition" as one of the keys to achieving an economically and environmentally sustainable world. Making this transition will require a thorough understanding of a broad range of science, technology, and policy issues at the interface of energy and the environment.

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 science and technology for DOE, ORNL also has extensive resources for understanding and addressing the environmental costs and benefits of energy production and use. In addition, through its science education programs, the Laboratory plays a role in preparing the work force that will address global needs for energy services in the 21st century.

As a result, the Laboratory is uniquely positioned to attack the long-term, large-scale, multidimensional problem of meeting national and global needs for future energy systems (see Table 4.4) that respect human health and the environment. The E^2SF Initiative will provide a mechanism for coordinating ORNL's comprehensive activities in energy and environmental science and technology (S&T), analysis, and assessment; for defining, selecting, and supporting new activities, with the aim of developing realistic pathways to a sustainable energy future; and for creating and using partnerships to bring together complementary resources in addressing this problem.

Table 4.4
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

4.4.1 • Approach

The E^2SF Initiative is envisioned as a strong and highly adaptive program that comprises

- an integrated R&D approach to the development of future energy systems that respect health and the environment;
- a broad program of 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 environmental systems; and
- R&D to create integrated systems for the analysis and assessment of technological, environmental, and socioeconomic factors in the development and deployment of systems for the safe, reliable, and efficient generation, storage, and distribution of energy.

The E^2SF Initiative will apply a systems approach to the closely linked tasks of improving resource efficiency and reducing the environmental impacts of existing energy sources; providing new sources of available and affordable energy; understanding and addressing the environmental costs and benefits of energy production and use; and assessing the technological, environmental, and socioeconomic factors that must be taken into account in the development of realistic pathways to a sustainable energy future.

The multidisciplinary nature of this complex problem presents a number of opportunities for teaming and collaboration, both within the Laboratory and with other organizations that possess complementary capabilities. Partnerships will be a critical element of the E^2SF Initiative.

4.4.2 • Resources

ORNL has been a leader in R&D at the intersection of energy, environmental, and economic issues throughout its history. *Energy Programs at Oak Ridge National Laboratory* (ORNL-6946, Lockheed Martin Energy Research, April 1999) documents the Laboratory's extensive history in sustainable energy programs and describes current work. Notable assets include programs in energy efficiency and renewable energy, fission energy, fossil energy, and fusion energy; science and technology programs (e.g., in chemical sciences and technologies, engineering sciences, instrumentation and measurement science and technology, 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, policy, and information activities. The strength and breadth of ORNL's capabilities represent an important and defining characteristic of the E^2SF Initiative.

Other ORNL resources are available to support the E^2SF Initiative. The Oak Ridge National Environmental Research Park and unique experimental field facilities in the park support large-scale environmental process research (see Sect. 3.4.3). Facilities such as the Bioprocessing R&D Center, the Buildings Technology Center, and the High Temperature Materials Laboratory support a broad range of energy-related R&D. Strengths in separations science and chemical processing (see Sect. 3.4.4) 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 E^2SF Initiative is also linked to the 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 E^2SF Initiative will draw 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.

Collectively, ORNL's resources make major contributions to meeting the challenges advanced in DOE's energy R&D portfolio: energy security, clean and affordable power, and efficient and productive energy use. The breadth of these resources and their integration of basic research, applied research, and technology development are important assets for the E^2SF Initiative.

4.4.3 • Initial Activities

In the first year of the E^2SF initiative, ORNL will carry out the following tasks:

- create a technology road map for clean power systems;
- conduct an interdisciplinary technical assessment to identify critical S&T issues;
- explore critical research needs to develop clean energy systems; and
- seek opportunities to establish linkages with and among current and planned efforts in energy and environmental R&D.

The results of these tasks will be used in constructing a long-term R&D program to resolve major uncertainties and unknowns, as described in Sect. 4.4.4.

4.4.3.1 • Technology Road Map for Clean Power Systems

At the request of DOE, ORNL plans to assist in the creation of a technology road map for clean power production. This effort will support the development of an organized structure for the R&D necessary to attain the goals set forth in the Comprehensive National Energy Strategy and in the DOE strategic plan; it will also supply information for the long-term E^2SF R&D program (see Sect. 4.4.4).

This organized structure will build on the federal government's substantial investment in energy R&D. Federal R&D programs, in addition to supporting broad national goals in energy security and environmental quality, represent a notable resource for strategies and technologies to be used in mitigating climate change and in supporting positive economic outcomes in areas such as sustainable resources, environmental protection and remediation, population growth, and utility restructuring.

The long-range goal of the roadmapping effort is the development of technologies that support a sustainable energy future while addressing global environmental concerns. The road map will address the need for R&D on fuel forms, conversion systems and materials, efficiency and recovery systems, end use, and process waste streams associated with each power system.

Technological areas of emphasis are renewable energy, highly efficient power generation, carbon sequestration, and power distribution. (Clean transportation systems are excluded from this effort because they will be addressed through other programs.)

4.4.3.2 • Identifying Critical S&T Issues

ORNL will conduct a technical assessment to document critical research questions, identify priority R&D, and explore the technological, environmental, and socioeconomic factors that must be addressed in developing and implementing clean energy systems. The assessment will provide a framework for integrating relevant past studies and enable a comprehensive understanding of the relationships and interdependencies among R&D priorities. This road map of critical S&T issues will be used to guide ORNL's R&D efforts over the next decade.

The assessment is envisioned as an inclusive process that relies on strong partnerships with academia, national laboratories, and other research institutions. By integrating these resources, ORNL will develop a systems perspective on the critical R&D challenges that must be addressed in order to ensure clean, affordable, widely available, and abundant energy for the United States and the world.

4.4.3.3 • Investing Discretionary Resources

Innovative research that supports the goals of the E^2SF Initiative has been identified as a target area for ORNL's Laboratory Directed R&D (LDRD) funds (see Sect. 6.2.1). Projects are expected to yield scientific advances and technology innovations in

- understanding the geological, chemical, material, biological, and physical processes that underpin the discovery, production, distribution, and use of energy, and exploiting this understanding in the development of clean and affordable energy;
- understanding the molecular, atmospheric, geological, ecological, and biological effects of energy use and energy by-products on the biosphere; and
- providing integrating capabilities in systems analysis to support the development and deployment of systems for the safe, reliable, and efficient production, generation, storage, and distribution of energy.

The advances and innovations resulting from these projects will contribute to the direction and development of the E^2SF Initiative. Specifically, LDRD support is expected to assist ORNL in the development of new R&D capabilities for characterizing and developing new energy sources, improving energy efficiency through advances in combustion sciences, developing integrated capabilities in bioenergy sciences, and identifying and resolving energy and environmental issues through advances in systems analysis capabilities.

4.4.3.4 • Building Linkages with Energy and Environmental S&T Programs

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. New programs are being planned and implemented to address emerging issues, such as bioenergy, climate change, and carbon management and sequestration.

DOE sponsors for energy and environmental S&T include the Office of Science (DOE-SC), the Office of Energy Efficiency and Renewable Energy, the Office of Fossil Energy, and the Office of Nuclear Energy, Science and Technology (see Sects. 2.4.4.1 and 2.4.4.2). Much of ORNL's work for other sponsors (see Sect. 2.4.4.6), 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. 6.1) contribute to ORNL's extensive foundation of expertise in energy and environmental S&T.

The E^2SF Initiative will leverage the results of these efforts in working to understand and minimize the environmental consequences of energy production and use, improve the resource efficiency of existing energy systems, and develop new options for energy services. Key activities for the E^2SF Initiative include planned work in global climate science, energy science and technology, large-scale environmental process research, and new energy sources.

Global Climate Science

Climate prediction with acceptable levels of uncertainty is one of the major goals of DOE's climate research efforts. Understanding how climate may change is also a prerequisite for identifying the energy and environmental R&D required to provide clean energy systems for the future. While the natural and physical sciences supporting the development of global circulation models (GCMs) are improving, scientific and computational challenges remain in the downscaling of GCM results to regional and local scales of resolution.

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, climate prediction, carbon sequestration, and regional climate science. ORNL strongly supports these initiatives and proposes a broad program in global climate change S&T to assist DOE in determining appropriate responses to national climate change issues.

ORNL's strengths in understanding both the potential impacts of global climate change and the technology options available to mitigate greenhouse gas emissions (the major contributor to climate change) are complemented by its expertise in advanced computing, information management, and integration of scientific, engineering, environmental, economic, and social science expertise.

Four ORNL divisions, supported by LDRD funds, are working together to establish a prototype regional climate science capability at ORNL to assist in supporting the planned Accelerated Climate Prediction Initiative (ACPI). As a first step, ORNL is directing R&D at coupling general circulation models, terrestrial models, and regional models; creating an interdivisional grid environment; and developing downscaling capabilities of GCM results to regional scales of resolution (see Sect. 4.3.2.1).

ORNL recently co-led a multilaboratory effort, sponsored by DOE, to identify key research needs for separating and capturing carbon dioxide from energy systems and sequestering it in the oceans, in geological formations, and in terrestrial ecosystems. The new DOE National Center for Research on Enhancing Carbon Sequestration in Terrestrial Ecosystems (CSITE)—which links the R&D capabilities of ORNL, Pacific Northwest National Laboratory (PNNL), Argonne National Laboratory (ANL), and several universities and research institutions—draws on experience gained in this effort. The center will conduct basic research that could lead to methods for sequestering substantial amounts of carbon in terrestrial ecosystems during the next 20 to 50 years. Research will initially focus on links between critical pathways and mechanisms for creating longer-lived carbon pools and ecosystem management strategies.

Energy Science and Technology

ORNL's capabilities and expertise are applied to a diversity of tasks in energy production, energy storage, and energy efficiency (see Sect. 2.4.4.2). Several specific R&D projects are of particular importance to the development of clean energy systems.

ORNL is developing and testing advanced coal gasification systems with increased resource efficiencies to reduce carbon emissions and other pollutants. R&D plans are being developed to produce the next generation of fuel cells using solid oxides. Energy efficiency research is focusing on advanced turbines, building envelopes, and efficiency improvements in internal combustion engines.

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 include the development of technologies to lower the cost of nuclear power and to make it more proliferation-resistant, the evaluation of concepts for low-power reactors designed to meet emerging requirements for process heat (district heating, desalination, hydrogen production, etc.), basic research on materials and fuels, and development of innovative concepts for storage and disposal of spent fuel. ORNL is also working to ensure acceptable levels of safety for nuclear power plants.

In the longer term, fusion energy could be an attractive element of the global energy system. 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 program that supports DOE's aim of demonstrating fusion's potential to be an economical, environmentally acceptable energy source.

Combustion is involved in a large percentage of energy conversion processes used to support human activity. With DOE support, ORNL has contributed to the development of measurements of combustion by-products and processes for their control, particularly for internal combustion engines, and to gains in combustion efficiency through materials R&D. FY 1999 LDRD funds are being used to develop advanced computer simulations of combustion after-treatment catalysis processes, where some of the greatest potential still lies. Longer range objectives are to achieve near-zero emissions (other than water and carbon dioxide) from combustion engines and to further the technical base for clean power from fuel cells (see Sect. 4.3.2.1).

Large-Scale Environmental Process Research

As described in Sect. 3.4.3, ORNL plans to integrate its expertise in environmental sciences, ecological process studies, landscape ecology, and global carbon science with its leading-edge capabilities for measurement, modeling, and monitoring of the environment to define and create new approaches to ecosystem process research. Leveraging and enhancing current assets in large-scale ecosystem manipulation, integrated data management, ecological modeling, measurement science and sensor development, and computational science will provide with ORNL capabilities to improve the understanding of large-scale environmental processes. A better understanding of environmental processes at multiple scales of resolution is critical to addressing the issues associated with developing clean energy systems.

New Energy Sources

ORNL is investing in two areas that offer significant potential as new sources of energy: methane hydrates and bioenergy.

Methane Hydrates • Methane hydrate—a crystalline solid consisting of methane molecules surrounded by frozen water molecules and found in arctic permafrost and deep ocean sediments—represents a vast energy resource. At the same time, carbon trapped in methane hydrate formations may represent more than twice the amount stored in all known fossil fuel reserves on earth and could be a significant potential risk factor for global warming. DOE's Office of Fossil Energy has recently undertaken a methane hydrates research program. A research team involving several ORNL divisions and universities is using LDRD funds to conduct exploratory research that includes forming an integrative seafloor process model and constructing a unique test facility to allow progress in developing and testing observational and sampling technologies; understanding the formation, accumulation, and stability of methane hydrates; and examining the biogeochemical fate and transport of methane and carbon dioxide.

Bioenergy • ORNL is expanding a research partnership with the National Renewable Energy Laboratory (NREL) to improve the use of bioenergy and biologically based product systems through research and integrated analysis. Through this partnership, several collaborative R&D programs are being planned to address plant biosciences and bioprocessing research for understanding and enabling the management of plant systems for efficient bioenergy and bioproducts. The goal of these R&D programs is to facilitate the use of basic plant biosciences in enabling advanced technologies for carbon management to mitigate future increases in atmospheric carbon dioxide. The partnership is also collaborating on the linkage of feedstock supply and conversion models to facilitate systems improvement approaches. ORNL and NREL propose to establish a National Bioenergy Center to foster expanded capabilities in renewable biologically based power, fuels, and chemicals. The center will help to catalyze the creation of new industries and will support technical improvements in efficient and economical use of biomass in agriculture and forest-based industries.

4.4.4 • Creating Integrated Solutions

The definition of realistic pathways to a sustainable energy future (characterized by abundant, affordable, environmentally acceptable, and widely available energy services) requires not only advances in S&T from a broad range of energy and environmental R&D, but also the development of new R&D capabilities for determining the consequences of these energy choices and methods of integrating this information to support further development and implementation of technologies and policies. This capability for integration is of singular importance to the development and implementation of clean energy systems for the 21st century.

In addition to providing a focal point for most of ORNL's energy and environmental R&D activities, the E^2SF Initiative will engage Laboratory resources in determining the consequences of energy choices. Tools and techniques will be developed for considering the social, economic, environmental, and security consequences of particular choices of energy technologies; and determining the policies that will be most effective in bringing about a sustainable energy future.

ORNL has unique resources for developing and applying these tools and techniques. Its expertise in the natural sciences, economics, and social science is applied 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, derived from its strengths in the engineering sciences and in energy sciences and technologies, 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, and engineering sciences and in technology development.

The E^2SF Initiative will build on these activities to create integrated solutions for addressing global energy needs, bringing together "best in class" expertise in partnerships that span disciplines and institutions. Within ORNL, the Center for Energy and Environmental Analysis, the Center for Global Environmental Studies, the Energy Division, and the Environmental Sciences Division will be key contributors to the E^2SF Initiative.

The Joint Institute for Energy and Environment, which focuses the resources of ORNL, the Tennessee Valley Authority, and the University of Tennessee on finding solutions to key national and international issues of energy, economics, and the environment, will be an important element of the E^2SF Initiative. The National Transportation Research Center, a partnership between the transportation programs at ORNL and the University of Tennessee, presents opportunities to develop integrated solutions for transportation issues that cut across energy and environment. Other partnerships (see Sect. 4.4.3.4) that will play key roles include the ORNL-NREL National Bioenergy Center; the DOE National Center for Research on Enhancing Carbon Sequestration in Terrestrial Ecosystems (CSITE), which links ORNL, PNNL, ANL, and several universities and research institutions; and the planned Regional Climate Network that brings together ORNL, ANL, PNNL, Lawrence Berkeley National Laboratory, and other institutions. 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.

Funding for the E^2SF 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 under development.

5 • Operations and Infrastructure

Operations functions [i.e., functions involving management of the Oak Ridge National Laboratory (ORNL) and support for its core programmatic and research functions] are carried out principally by the Laboratory's Central Management Offices, the Business Management Organization, and the Operations, Environment, Safety, and Health (OES&H) Directorate. Since January 1, 1996, ORNL has been managed for the U.S. Department of Energy (DOE) by Lockheed Martin Energy Research Corporation (LMER). A new management and operation (M&O) contract, which goes into effect on April 1, 2000, has been awarded to UT-Battelle, LLC, a partnership between the University of Tennessee and Battelle Memorial Institute.

5.1 • Integrated Safety Management

5.1.1 • Integrated Safety Management System

ORNL's commitment to integrated safety management (ISM) and to the accomplishment of its mission assignments in a safe and effective manner is documented in a Laboratory directive, *ORNL Integrated Safety Management Policy Statement,* ORNL-LM-001, January 1, 1998. ORNL is implementing an ISM system (ISMS) to ensure that safety considerations are integrated into the planning and execution of research and support activities. An ISMS Implementation Committee has been established, and a Special Assistant to the Office of the Laboratory Director has been appointed to work with the committee in coordinating the implementation of the ISMS program.

The ORNL ISMS program is described in detail in *ORNL Integrated Safety Management System (ISMS) Program Description*, ORNL-LM-003, July 10, 1998. As outlined in the program description, each ORNL line organization has at least one ISMS plan to customize the ISMS principles and core functions to its operations. For complex or special-hazard situations, organizations may choose to have additional ISMS plans tailored to specific programs or facilities. Both the program description and organization-specific ISMS plans will be updated as necessary, based on ongoing self-assessment activities that identify gaps to be filled and/or on changes in work scope.

Phase I verification of ORNL's ISMS program was completed in April 1999. Full implementation is expected by the end of February 2000.

In support of the ISMS program, a subcontract has been established with Performance Improvement International (PII) to improve safety performance at ORNL. The PII approach to accident reduction focuses on prevention of human errors leading to events, detection of event precursors, and correction of event causes. It also addresses the critical links between equipment performance, management performance, human performance, and organizational and programmatic performance.

The focus of the training is on ORNL's nuclear operations. Using the results of a culture survey conducted in selected nuclear and support divisions, PII is developing and conducting training courses focusing on human error reduction for managers, supervisors, and individual contributors. Training of nuclear facilities managers, supervisors, and workers has begun. A second phase of training will include employees from other selected facilities. The PII contract lasts through FY 2000.

With other contractors to DOE's Oak Ridge Operations Office (DOE-ORO), LMER sponsored a November 1999 workshop, "Making Integrated Safety Management a Reality." The purpose of the workshop was to draw on experiences with implementing ISM across all segments of the Department and focus on institutionalization of ISM and the role of the worker in effective implementation of ISM at the activity level.

5.1.2 • Goals and Objectives

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

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

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

5.1.3 • Current Conditions

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

ORNL also operates one reactor, the High Flux Isotope Reactor. Several other reactors have been permanently shut down and are awaiting 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 radioisotopes 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.

The diversity of ORNL's R&D and support activities creates both challenges and opportunities. ORNL has played a leadership role in the development of a number of initiatives for DOE's Office of Science, such as sitewide Work Smart standards and oversight reduction. This has resulted in opportunities for improvement at all DOE facilities. In addition, the Work Smart standards effort provided the basis for the reengineering of ORNL's ES&H and quality (ESH&Q) functions (see Sect. 5.3.4.2), which in turn is a key to the Laboratory's implementation of ISM (see Sect. 5.1.1).

Limits on ES&H funding, continuing emphasis on overhead reduction, and changing relationships with other DOE facilities and contractors in Oak Ridge challenge program continuity and improvements. ORNL works with Lockheed Martin Energy Systems, Inc., the M&O contractor for DOE's Oak Ridge Y-12 Plant, and with Bechtel Jacobs in its efforts to provide an operating environment that supports the accomplishment of mission assignments in a safe, compliant, and cost-effective manner.

5.1.4 • Plans

ORNL's plans for ensuring ES&H compliance are documented in the *FY 1999 Environmental, Safety, Health, Quality, and Infrastructure Management Plan for the Oak Ridge National Laboratory* (ORNL/M-6616, Lockheed Martin Energy Research Corp., November 1998) and in annual ES&H, quality, and infrastructure (ESHQ&I) budget formulation submissions.

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

5.1.5 • Environmental Management Activities

EM activities at ORNL are managed by Bechtel Jacobs. Records of Decision to address future remedial actions in the Bethel Valley and Melton Valley areas of ORNL are now being finalized. ORNL participates as a stakeholder in these decision processes. The Environmental Management Programs organization and the Office of Environmental Protection in the Laboratory's OES&H Directorate continue to work with Bechtel Jacobs and DOE-ORO to ensure effective remediation of legacy contamination.

5.1.6 • Waste Management Activities

Responsibility for waste management at ORNL was transferred to Bechtel Jacobs in FY 1999. A Laboratory Waste Services Organization (LWSO) has been established to provide the interface between ORNL waste generators and the Bechtel Jacobs waste disposition contractors. LWSO supports the research community in four primary areas: generator interface, waste acceptance, waste handling, and program planning.

The generator interface function is performed by technical experts who work with the generating divisions to properly characterize, package, and temporarily store wastes for pickup by Bechtel Jacobs. The waste acceptance group provides an independent check of the waste certification paperwork and the physical condition of the waste to ensure that the waste will not be rejected by Bechtel Jacobs vendors. Waste handling capability is provided to move wastes from satellite staging areas to 90-day areas and on to Bechtel Jacobs for final disposition. Program planning is available to assist waste generators with evaluating options for waste generation, pollution prevention, and waste treatment and disposal to minimize costs and provide the best disposition approach for the variety of ORNL waste types.

Funding for LWSO operation is provided through Laboratory overhead for functions that support the entire Laboratory (program planning and overall administration) and through a generator chargeback allocation for direct support to waste packaging and handling. Divisions will be charged in direct proportion to the amount of waste that they generate when the program is fully instituted in FY 2000.

Responsibility for management of newly generated waste may be transferred from DOE's Office of Environmental Management to the Office of Science in the FY 2001–FY 2002 time frame. ORNL is planning for execution of the responsibilities associated with this transfer.

5.2 • Communication and Trust

5.2.1 • Public Information and Outreach Activities

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

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

A media relations program provides information about ORNL activities and their significance to media representatives through the distribution of news releases, through telephone and face-to-face contacts made by ORNL Communications and Public Affairs staff, and through regular updates of ORNL's home page and "Newsroom" page on the World Wide Web. More than 480 contacts with media representatives were made in FY 1999.

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

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

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

Commissioner of Economic and Community Development on science and technology issues confronting state government.

ORNL periodically opens its doors to thousands of area residents for Community Day, a full day of tours and festivities celebrating science and its importance to East Tennessee. The Laboratory has also hosted Family Days and Take Your Child to Work Days.

ORNL is a partner with DOE, Lockheed Martin Energy Systems, Inc., the National Park Service, and the Knoxville Convention and Visitors Bureau in the Gateway Regional Visitors Center on Knoxville's riverfront. Lockheed Martin Corporation has provided financial patronage for the center, which features permanent exhibits that include ORNL science and technology. ORNL Communications and Public Affairs staff provided significant support in developing exhibits for the center and preparing for its April 1999 opening.

ORNL's historic Graphite Reactor and the New Bethel Church Interpretive Center are open to the public seven days a week as part of a self-guided driving tour. Both are featured on the Tennessee Heritage Trail listing developed by the state's Department of Tourist Development. Visitors to ORNL may also participate in prearranged general orientation tours or customized tours; some 2,000 students, business people, and technical people use this option each year. The Oak Ridge Public Tour, originating at the American Museum of Science and Energy in the city of Oak Ridge, is available from March through October. In 1999, this program served 2,839 visitors representing 50 states and 24 other nations. Since its inception 5 years ago, more than 11,800 visitors from all 50 states and 54 other nations have visited ORNL through these public tours, which are also 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 pre-college students.

Management of the American Museum of Science and Energy is now part of ORNL's scope of work. ORNL is working with DOE and Enterprise Advisory Systems, Inc., which operates the museum under subcontract to ORNL's M&O contractor, to strengthen public awareness of DOE programs and activities. ORNL also plans to expand communications activities related to the Spallation Neutron Source, broaden its community outreach, and improve the flow of information to its employees.

5.2.2 • Information Resource Management

ORNL is committed to managing and using its technical and administrative information as institutional and multinational assets. Steps are being taken to strengthen management attention to information as an asset and to improve user involvement in the effective use of information resources. Objectives for the coordinated information infrastructure include

- increased desktop access to information via Internet technologies;
- acquisition or development of tools, techniques, and applications that support the evolving information needs of ORNL;
- maximum participation in deployment of corporate applications to enable appropriate implementation for ORNL;

- efficient records management using electronic retrieval systems; and
- enhanced electronic distribution of documents (i.e., cradle-to-grave electronic publishing and dissemination).

ORNL uses its information management expertise and extensive investments in computing and networking technology to provide a networked information management strategy. An Information Infrastructure Strategic Plan has been developed under the direction of the ORNL Chief Information Officer. The strategic plan identifies six 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.
- Transparency to the enterprise—nonemployee and interlaboratory access and support.
- Intelligent tools for leveraging knowledge—improved interfaces and intelligent agents.
- Integration of ORNL information enterprise—information architecture for more efficient use of systems.
- Computing as a tool for research—core resources required to support the needs of the scientific staff; modeling and simulation support.

Implementation teams will develop roadmaps for achieving improved user experiences in all of these areas.

The World Wide Web is the interface of choice for the Laboratory's internal administrative information and business applications and for global communications about ORNL's research, technology, products, and services. The Web has become 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 (see Sect. 5.2.2.2). The ORNL public Web site provides a means for the public to submit information, make comments, and request information. Web servers are becoming the principal distribution point for information products from ORNL's information centers and databases. The growth and popularity of the Internet have allowed ORNL to share more information than ever before with a global audience.

Subscriptions to key electronic information sources maximize the availability of information to ORNL staff. Access to such information has recently been enhanced through the efforts of a consortium of libraries at DOE laboratories. The Laboratory's Research Libraries are adding half a million dollars worth of electronic journals, at no additional cost to the Laboratory, effectively tripling the size of the electronic journal collection.

Core information management and information technology services are provided by the ORNL Computing, Information, and Networking Division and the Office of the Chief Information Officer. These organizations coordinate with the Instrumentation and Controls Division to provide the strategic framework for information resource management for the Laboratory. Customer committees work to ensure that these services address the concerns of ORNL staff; these committees include the Administrative Computing Steering Committee, the SAP Users' Group, the Scientific Computing User Advisory Committee, the Network Forum, the Internet Technologies Working Group, the Electronic Information Advisory Group, and the Library Advisory Committee.

5.2.2.1 • Scientific and Technical Information

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

Proper management enhances the value of this information as a tool for executing DOE missions and increases its availability to audiences that include U.S. industry and the public.

ORNL is working aggressively to increase its electronic delivery of STI. Much of the Laboratory's STI is now available through internal and external Web sites, and ORNL has also accepted the responsibility of providing at least 50% of the documentation submitted to DOE's Office of Scientific and Technical Information (OSTI) in electronic format.

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

5.2.2.2 • Administrative Information

A single business software system, SAP R/3, replaced most of ORNL's core business applications in October 1998. A users' group has been formed (1) to ensure that end users are informed about SAP activities and that their needs are recognized and met and (2) to assist ORNL leaders in making decisions about business rules and their implementation.

ORNL and Lockheed Martin Energy Systems, Inc., the M&O contractor for the Oak Ridge Y-12 Plant, share several systems (software, hardware, and related data) that are considered necessary to support continued functioning of business. With the change to a new M&O contractor at ORNL effective April 1, 2000, work is under way to separate these systems. Plans are for all shared systems to be completely separate by the end of FY 2000.

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. The Administrative Computing Steering Committee is the focus for many of these tasks, which include

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

5.2.2.3 • Year 2000 Compliance

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

With the realization in mid-FY 1998 that the Y2K problem was not limited to personal computers (PCs) and associated software, a Y2K project team was formed to manage the increased scope and formality of the effort. The team is responsible for responding to directions from DOE and Lockheed Martin Corporation and for assisting line managers by providing them with technical advice and helping them to fulfill their responsibilities to identify and renovate systems under their control. The project team consists of a project manager and members from the technical, management, legal, and contracts staff. It reports to the Laboratory's deputy director for operations and administration.

Through March 31, 1999, efforts focused on remediation of hardware, software, and data systems affected by the Y2K problem and on planning to manage unmitigated Y2K-related problems that arise during the Y2K transition. ORNL identified more than 700 Y2K-impacted systems and classified them according to DOE guidance as either mission-essential or non-mission-essential systems. All systems were tracked for full remediation by March 31, 1999; mission-essential systems were also tracked on the national level.

ORNL participated in a national "9-9-99" drill in September 1999, and an electric power consumption minimization exercise was conducted in October 1999. Y2K efforts are now focused on planning to mitigate potential Y2K-related vulnerabilities (internal and external to ORNL) that arise during and shortly after the Y2K transition.

5.3 • Management Practices

5.3.1 • Human Resources

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

In December 1998, labor and management organizations across DOE's Oak Ridge complex jointly organized a Labor-Management Prayer Breakfast. Guest speakers included Congressman Zach Wamp and Cotton Ivy, former Tennessee Commissioner of Agriculture. The event was deemed a success, and plans are being made to hold the breakfast annually. Guests from the Tennessee Center for Labor Management also expressed their hope of seeing such events organized in the middle and western regions of the state. The Oak Ridge Labor-Management Prayer Breakfast has been nominated for a Tennessee Award for Excellence. This award is presented by the Tennessee Labor-Management Conference to an employer-employee partnership on the basis of the nominee's leadership, involvement, and visibility in developing and maintaining a quality work force and an environment for cooperative labor-management relations within the organization.

Human Resources continues to reengineer its programs, systems, and processes to support ORNL's overall reengineering efforts (see Sect. 5.3.4.2) and the culture change necessary for these efforts to be successful. Primary goals for Human Resources reengineering are to

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

The Human Resources Reengineering Team chartered in 1996 made more than 50 specific recommendations to streamline and simplify human resources processes and to help ORNL attract, retain, and motivate the talent needed to meet customer and Laboratory missions in today's competitive environment. Many of these recommendations were implemented in FY 1999. Some, especially those relating to a new pay system, are under development for implementation by April 2000.

The final modules of a new human resources information system, developed as part of the SAP R/3 implementation, were implemented in October 1999. Revision of human resources policies and procedures to support the desired culture change is under way. Initiatives aimed at supporting the "work force of the future," such as increased flexibility in work schedules and a flexible workplace program to allow "telecommuting" by selected employees, have been implemented. Other key actions are being taken in performance management and compensation and in work force diversity.

5.3.1.1 • Performance Management and Compensation

ORNL's performance management process has been streamlined, and line managers are being given new tools to assist them in managing performance. A competency-based performance management system, including an integrated employee development module, was piloted in FY 1999. The system draws on seven underlying job competencies that have been identified, defined, and aligned with ORNL strategies. A new and simplified job worth/ job evaluation system is under development. The goal is to place the responsibility for most decision-making about human relations in the line organizations. Information, tools, and guidelines to support line managers have been introduced, as well as analyses, summary overviews, and reporting of results for senior management review.

The need to increase the competitiveness of ORNL salaries was a key finding by the Human Resources Reengineering Team. A program is now in place to strengthen the R&D salary program in critical areas where the Laboratory is not competitive.

5.3.1.2 • Diversity

ORNL is committed to achieving its strategic business objectives by capitalizing on the diversity of its work force. The Diversity Plan outlines means for promoting a high-performance, diverse, and inclusive organization. A Diversity Leadership Team, led by the Laboratory's deputy director for operations and administration, is charged with monitoring progress toward meeting the plan's objectives.

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

During a period of limited hiring and reductions in the work force, ORNL has continued to emphasize its diversity program. ORNL has been recognized by DOE for significant progress in addressing Equal Employment Opportunity/Affirmative Action (EEO/AA) and promoting work force diversity. ORNL is committed to increasing the number of minorities in senior Officials & Managers (O&M) and individual contributor positions. Efforts in this area are guided both by the M&O contract for the Laboratory and by metrics associated with the Business Management Review process.

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

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

5.3.2 • Site and Facilities Management

ORNL is committed to good stewardship of its resources, both in management of existing facilities and in planning for future needs. The Laboratory's M&O contractor is responsible for (1) site and facility planning for ORNL and (2) management and planning for most of the undeveloped land area of the 14,260-ha (34,513-acre) Oak Ridge Reservation. The *ORNL Land and Facilities Plan* (ORNL/M-6714, August 1999; 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; on the World Wide Web at 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.

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

Although funding constraints will continue to limit the amount of work that can be done to remedy this situation, the implementation of recommendations made by the Engineering Design and Construction Reengineering Team (see Sect. 5.3.4.2) is reducing the cost of construction and upgrades. The Risk Ranking Board (see Sect. 5.1.4) facilitates a consistent, integrated ranking of Laboratory requirements, as will the planned expansion of a business risk methodology to assess requirements for sitewide utility systems. The development of this integrated process will support the most effective allocation of scarce resources.

5.3.2.1 • Laboratory Description

ORNL's main site encompasses approximately 440 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 Oak Ridge Y-12 Plant and leases some space off site.

As indicated in Table 5.1, buildings at the Melton Valley and Bethel Valley sites and Copper Ridge comprise approximately 3.4 million gross square feet of building space; at the Y-12 Plant, ORNL use accounts for almost 1.4 million gross square feet of building space.

Facilities that have been accepted into DOE's EM program and those that are part of the waste management systems managed by Bechtel Jacobs under the M&I contract for environmental management have been transferred to Bechtel Jacobs to facilitate the accomplishment of contractual responsibilities. With the exception of these facilities, ORNL has full responsibility for its Bethel Valley and Melton Valley sites and surrounding areas. ORNL is also responsible for management of an 8,530-ha (21,076-acre) portion of the 14,260-ha (34,513-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 Plant, ORNL has responsibility for building maintenance and ESH&Q functions as approved by Memoranda of Understanding between ORNL and Y-12.

The ORNL site has many functions and requirements similar to those of a small city. It is supported by a dedicated fire department, a medical center, a security force, and a steam plant. Amenities include 60 km (37 miles) of paved roads, 290 km (180 miles) of unpaved roads, 8,230 m (27,000 ft) of steam lines, 30,480 m (100,000 ft) of treated water piping, and 50 ha (115 acres) of mowed grounds.

Replacement plant value is presented in Table 5.2. The overall condition of the space is shown in Fig. 5.1, with use and condition of space in Fig. 5.2 and a summary of building age in Fig. 5.3. Maintenance deficiency costs by discipline based on Condition Assessment Survey results are shown in Fig. 5.4. Space occupied by ORNL at the Y-12 Plant is not included in Figs. 5.1–5.4. The landlord for the Y-12 Plant is the Department of Energy's Office of Defense Programs.

5.3.2.2 • Trends

ORNL's strategic plan (see Sect. 3) includes a strategy for consolidation of Laboratory operations at the main ORNL site. In support of this strategy, five facilities at the Oak Ridge Y-12 Plant that were formerly occupied by ORNL staff, primarily in the Biology Complex, have been completely vacated in the last year. The bulk of the facility space (more than 370,000 square feet) is not contaminated and is not, therefore, a candidate for transfer to the EM program. It will be managed as landlord facilities until final disposition is determined. 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).

Six contaminated facilities and eight noncontaminated facilities were added to the surplus facility list in FY 1999. Three office trailers totaling approximately 3000 square feet were removed in FY 1999.

New facilities added in FY 1999 include the High Flux Isotope Reactor (HFIR) Cold Source Building, the HFIR Neutron Sciences Support Building, and the Boiler No. 6 Addition at Building 2519.

Table 5.1
ORNL space distribution

Location	Buildings		Trailers		Total space, ft^2
	Number	Space, ft^2	Number	Space, ft^2	
ORNL main site					
LMER	307	2,927,240	56	49,924	2,977,164
Bechtel Jacobs	121	424,842	33	26,918	451,760
Subtotal, ORNL main site	428	3,352,082	89	80,275	3,428,924
ORNL at Y-12	29	1,379,230	2	2,436	1,381,666
Leased off-site	3	62,169	—	—	62,169
Total	**460**	**4,793,481**	**91**	**82,711**	**4,872,759**

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

Facility type	Replacement cost
Buildings and structures	3,507
Utility systems	TBD[a]
All other	TBD
Total	TBD

[a]TBD = to be determined.

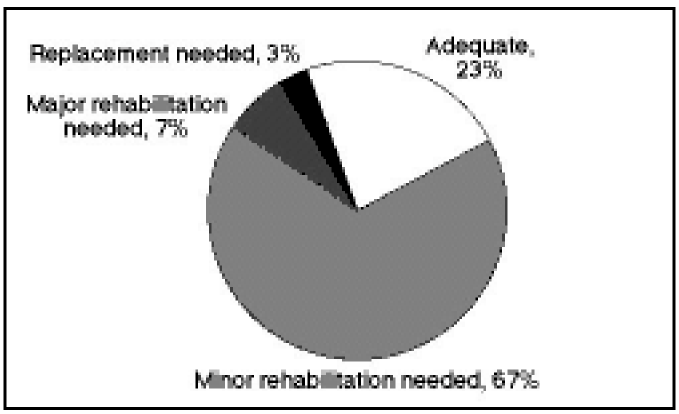


Figure 5.1
Condition of ORNL space, based on cost of modification or repair as a percentage of replacement value. Adequate: cost < 10%. Minor rehabilitation: cost 10%–25%. Major rehabilitation: cost >25%–60%. Replacement: cost > 60%.

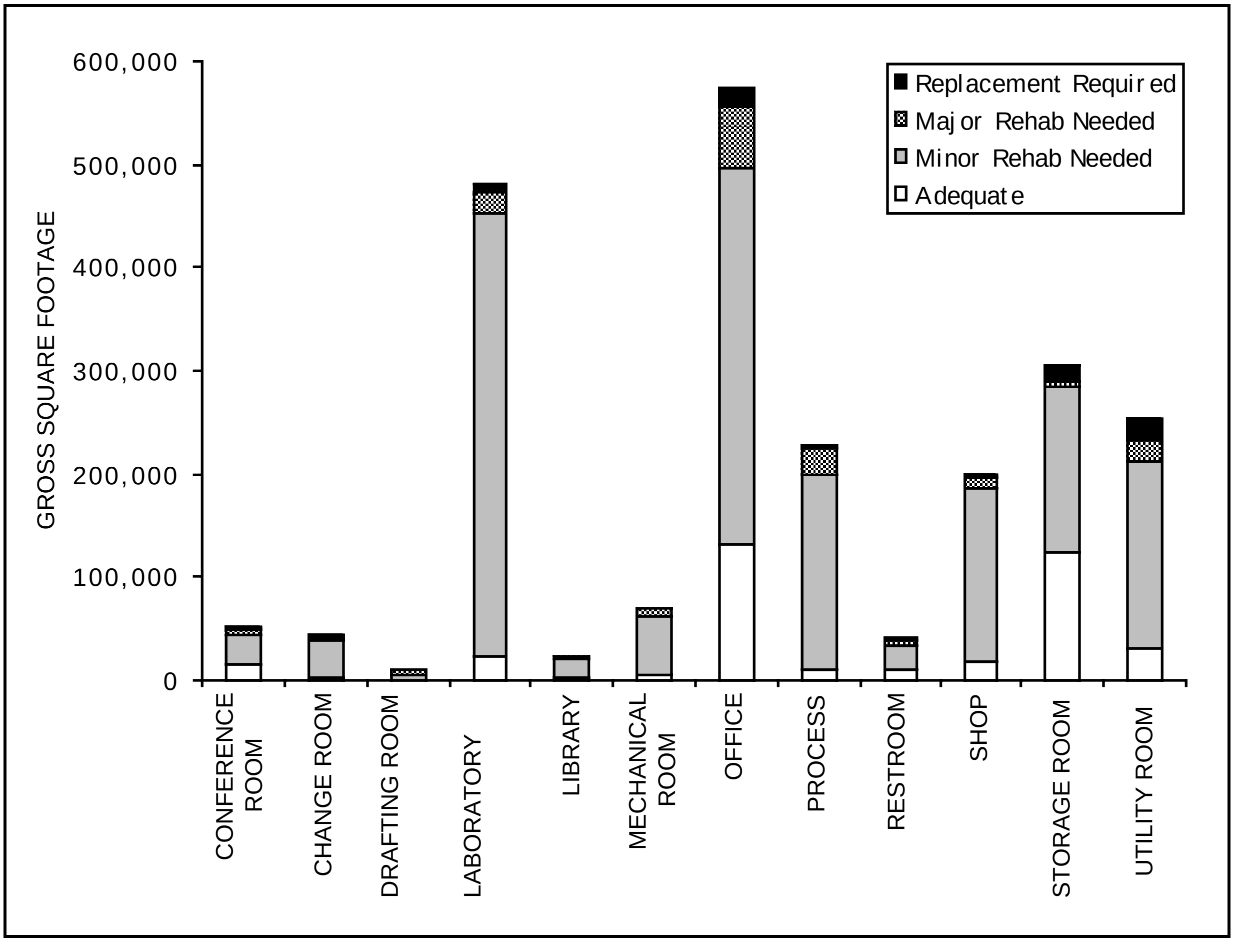


Figure 5.2
Use and condition of ORNL space. Condition is based on cost of modification or repair as a percentage of replacement value. Adequate: cost < 10%. Minor rehabilitation: cost 10%–25%. Major rehabilitation: cost >25%–60%. Replacement: cost > 60%.

5.3.2.3 • Facilities Plans and Options

Facilities plans and options for ORNL are described in the *ORNL Land and Facilities Plan.* The *Environmental, Safety, Health, Quality, and Infrastructure Management Plan for the Oak Ridge National Laboratory* (ORNL/M-6616, November 1998) addresses infrastructure planning, and the annual environmental, safety, health, quality, and infrastructure budget formulation submission contains a detailed listing of proposed projects and upgrades and serves as the primary document to support planning and budgeting efforts in this area. The ORNL site planning methodology is shown in Fig. 5.5.

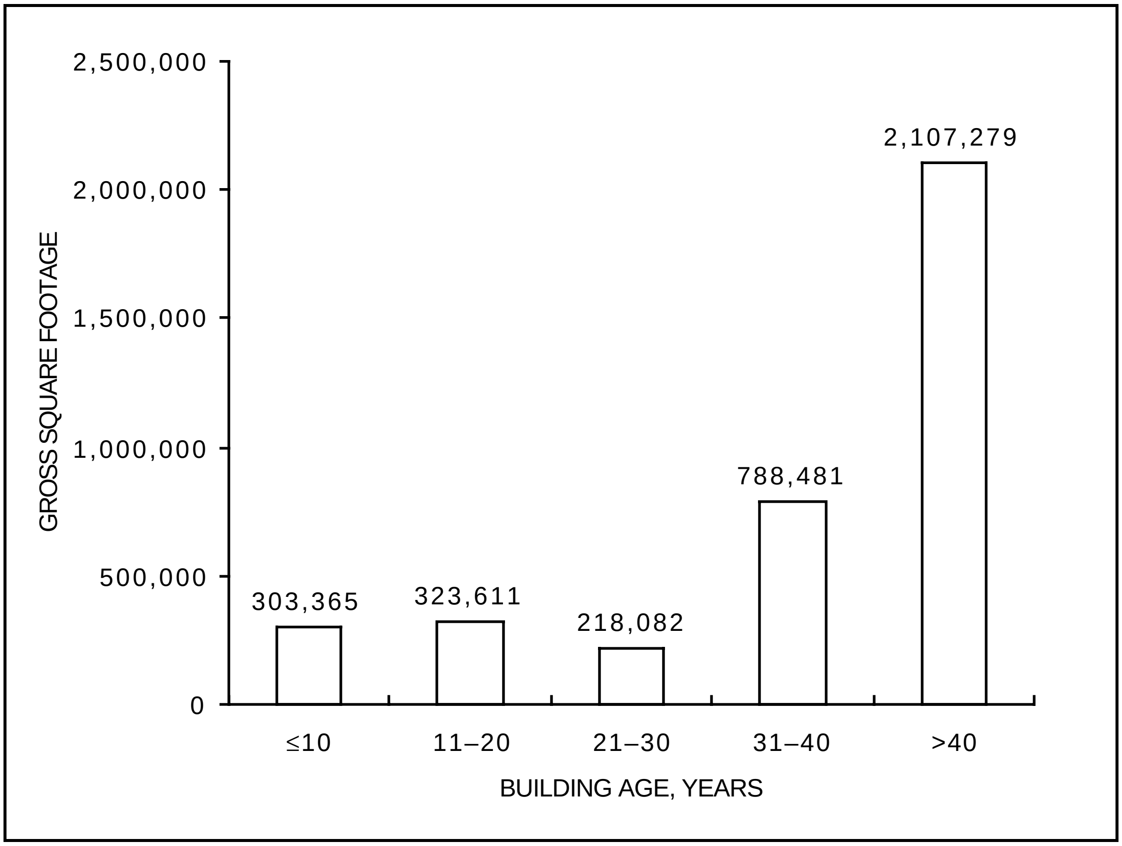


Figure 5.3
Age of ORNL buildings.

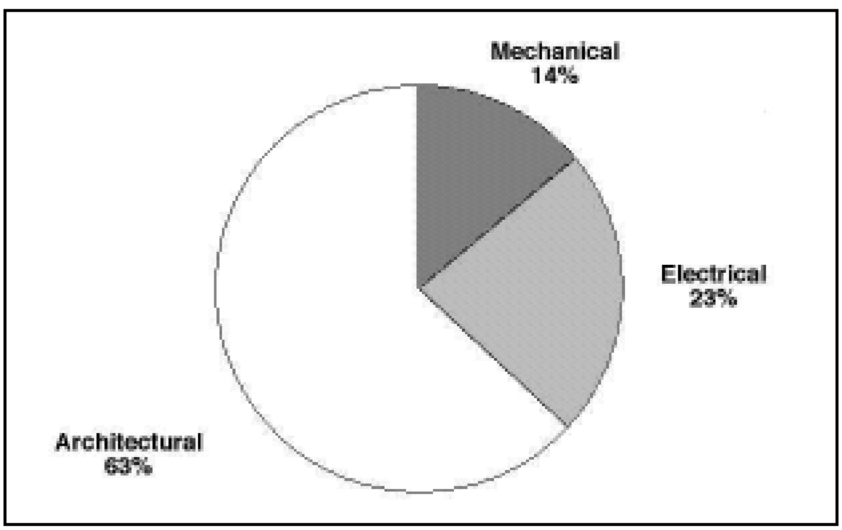


Figure 5.4
Condition Assessment Survey deficiency cost by discipline.

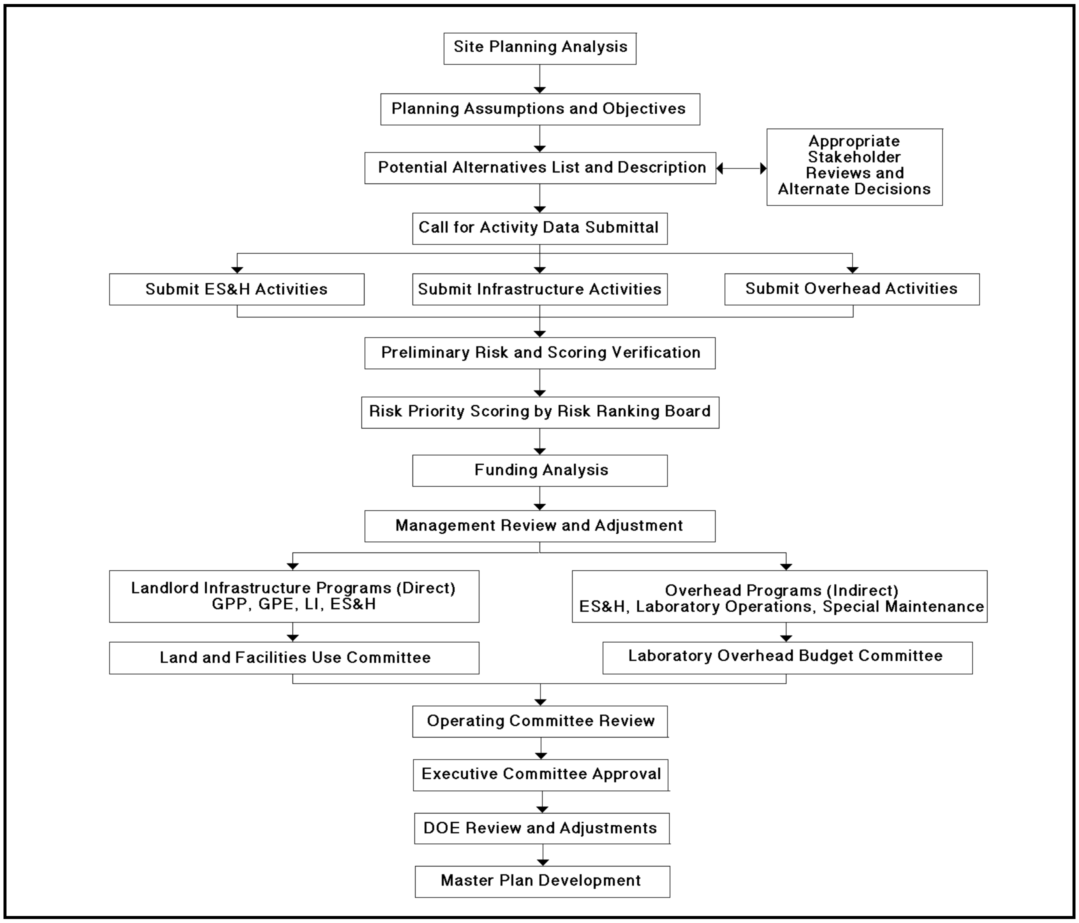


Figure 5.5
ORNL site planning methodology.

Development Objectives

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

Development Guidelines

Three premises guide land and facilities development:

- The linear pattern of the main ORNL site, which derives from the local ridge and valley terrain, will continue to serve as the general physical form determinant. Areas within Bethel Valley and Melton Valley will be divided into zones of related activity (according to function, program, or division). Design will generally resemble that of a university campus. Planned development at ORNL is shown in Fig. 5.6.

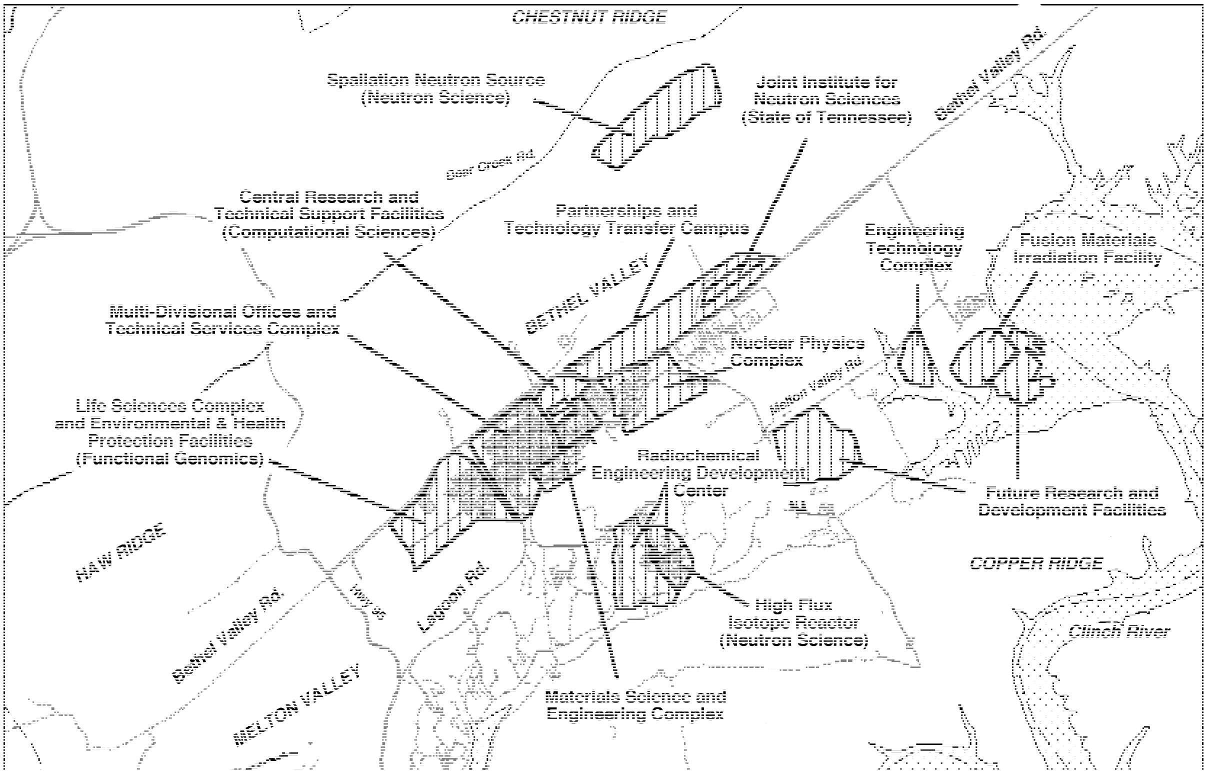


Figure 5.6
Planned development for ORNL.

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

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

The Laboratory's major initiatives, described in Sect. 4, will require the construction of new facilities. In support of the neutron sciences initiative, the Chestnut Ridge area north of the main ORNL complex is the preferred site for the Spallation Neutron Source and for the Joint Institute for Neutron Sciences. The High Flux Isotope Reactor (HFIR) upgrade and refurbishment is under way in the Melton Valley area. Sites have been identified in the Bethel Valley area for the Laboratory for Comparative and Functional Genomics to support the complex biological systems initiative and for computing facilities to support the terascale computing and simulation science initiative. A Bethel Valley site has been identified for the Advanced Materials Characterization Laboratory proposed in Sect. 3.4.2.

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

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

ORNL's programs require a variety of buildings and equipment, including specialized experimental laboratories, a large complement of office space, and major utility and waste disposal facilities. Because ORNL has one of the oldest physical plants in the DOE laboratory system, continuing efforts are needed to enable extensive renovations and rehabilitation of general-purpose buildings and utility systems. Projected requirements for major facility construction in support of ORNL's vision and missions are included in Tables 5.3 and 5.4.

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 research and development activities, (3) upgrades and replacement of site and facility utility systems, and (4) disposition of inactive/surplus facilities.

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

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

Additional funding will be needed to bring buildings and utilities up to acceptable standards and maintain them. General plant projects (GPPs) and line items are planned to upgrade and replace or renovate various infrastructure systems, including electrical, fire protection, heating/ventilation/air conditioning (HVAC), and water systems. Table 5.3 shows currently funded construction projects, and Table 5.4 shows planned construction projects.

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

Requirements in these areas continue to grow, and projected funding levels remain well below the level needed to maintain the Laboratory's infrastructure in good condition. The projected budget for these activities in FY 2000 and FY 2001 is $7.75 million annually. The identified requirements of $16.6 million in FY 2000 and $21.0 million in FY 2001 significantly exceed the available resources. DOE's Multiprogram Energy Laboratory Facility Support (MEL-FS) line item budget of $21 million is inadequate to meet the needs of all of the multiprogram energy laboratories. To most effectively meet the needs of ORNL programs, GPP and GPE funding levels need to return to pre-FY 1996 levels, and MEL-FS line item funding should be significantly increased.

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

	TEC[b]	Fiscal year 1998	1999	2000	2001
Research Program Line Item Projects					
Accelerator and Reactor Improvements and Modifications	9.80	4.50			
Spallation Neutron Source	1,333.0		130.0	117.90	281.00
EM Program Line Item Projects					
Bethel Valley FFA Upgrades	13.80	1.90			
Melton Valley Storage Tanks Capacity Increase	48.00	1.22			
General Purpose Facility Line Item Projects					
Replace deteriorated roofing	15.00	3.99	4.91	0.75	
Electrical systems upgrade	5.90			0.40	5.50
Steam plant upgrade (boiler addition)	5.30	3.40	1.90		
General Plant Projects—Landlord					
Environmental and Life Sciences Laboratory	2.70	0.20	2.30	0.20	
Fuel oil storage tank	1.10		1.10		
HFIR cooling tower replacement	4.45			1.80	2.65
HFIR User Facility	0.30	0.30			
Neutron Science Support Facility	1.74	1.56	0.05		
3000-scfm air compressor, Building 2519	1.25	1.25			
Fire protection upgrades	3.00		0.65	0.15	1.00
West end steam system	1.82	0.20	0.07		
Upgrade condensate return system	0.50	0.20	0.30		
Replacement of No. 1 water reservoir	1.70			1.70	
Nanoscience Metrology and Instrumentation Laboratory	1.30			0.30	1.00
Total funded construction	**1,450.66**	**18.72**	**141.28**	**123.20**	**291.15**

[a]Construction data as of December1999.
[b]TEC = total estimated cost. May include funding from prior years.

The amount of maintenance funding provided through Laboratory overhead over the past two years has been level at $14.7 million. Deferred maintenance requirements exceed $32 million at present. Some additional funding for noncapital maintenance upgrades and facility improvements will be available from the space charge system in the future.

5.3.2.5 • Asset Management, Space Management, and Inactive Surplus Facilities

ORNL initiated a space charge system in FY 1998 to promote more effective and efficient use of ORNL buildings and to provide a more equitable distribution of the costs associated with maintaining these buildings. Facility space is divided into three categories: conditioned, unconditioned, and direct.

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

	TEC[b]	Fiscal year 2000	2001	2002	2003	2004
Research Program Line Item Projects						
Laboratory for Comparative & Functional Genomics	13.9		2.5	10.0	1.4	
Thermal Neutron (HB-2) Guide Hall at HFIR	26.0		13.0	13.0		
Advanced Materials Characterization Laboratory	27.0			12.0	15.0	
40-teraflops Computer Facilities	13.0			2.0	9.0	2.0
Computational Sciences Facility	7.0			1.0	4.0	2.0
General Purpose Facility Line Item Projects						
Central Services and Conference Center	6.1				1.5	4.6
Fire Protection Systems Upgrade	5.9		0.6	3.8	1.5	
Laboratory Facilities Ventilation Systems Upgrade	5.5				5.5	
Laboratory Facilities HVAC Upgrades	7.1		0.5	3.0	3.6	
Support Services Facility	14.4			6.0	7.0	1.4
General Plant Projects—Landlord						
Computer facility upgrades	1.0		1.0			
Seismic upgrades, Building 1506	0.5	0.5				
HVAC upgrades	3.5				2.3	1.2
Water systems upgrade, 1000 area	0.5			0.5		
Building 4511 cooling tower replacement	1.4			1.4		
Transportation and Packaging Facility	3.1			0.5	2.6	
Lambert Quarry signage and fencing	0.1		0.1			
Mailroom facility	0.8				0.8	
Sanitary waste transfer station	0.2				0.2	
Upgrade condensate removal system	1.1			1.1		
Boiler No. 5 upgrade, Building 2519	0.5			0.5		
Maintenance shop addition, Building 4509	1.0			1.0		
Building electrical system upgrades	0.9		0.5	0.4		
Replace Building 1506 greenhouses	1.3			1.3		
Security perimeter reconfiguration	0.9	0.4	0.5			
Water systems upgrade, 7600 area	1.2			1.2		
HFIR entrance addition	1.0				1.0	
Extend water main, 7000 area	1.0				1.0	
Child care and fitness center	2.0	0.3	1.7			
Building 7002 changehouse upgrade	0.5				0.5	
Replace East End water softener, Steam Plant	0.8				0.8	
Elevator upgrade	4.2				1.3	1.4
Restore natural gas distribution system	1.8					1.8
Metrology laboratory, Building 3500	1.0					1.0
Ventilation system upgrade	4.6			0.4	2.2	2.0
ORNL Technical Support Center	2.5					2.5
Eyewash, safety shower, and water system upgrades	2.9		1.9	1.0		
Demolition and replacement, Building 6003	1.9				1.9	
Road and parking lot paving	1.0			0.5		0.5
Auxiliary systems upgrade	0.3					0.3
Total proposed construction	**169.4**	**1.2**	**22.3**	**60.6**	**63.1**	**20.7**

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

Conditioned space is space with HVAC capability (e.g., offices, laboratories, and conference rooms). Unconditional space (e.g., warehouses or storage facilities) is not HVAC capable. The “direct” category comprises major dedicated experimental facilities with a sole purpose. Distribution of costs for these facilities on a square-footage basis was judged inequitable, because the majority of their costs are already direct charged to program sponsors. Therefore, they are direct charged only for actual support and services provided.

Space charge components 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.

As a result of space charge implementation, approximately 370,000 square feet of marginal space has been vacated. Approximately 343,000 square feet of this space has been offered for reindustrialization. To date, however, no interest in these facilities has been expressed by the commercial sector. Deactivation of these facilities was initiated in FY 1999 and will be completed by FY 2001. The Y-12 Plant has requested transfer of 12,000 square feet of this space; 15,000 square feet is contaminated and will be proposed for inclusion in the EM program in FY 2002.

At ORNL, 156 facilities have been identified as inactive or surplus. Decontamination, demolition, disposal, or renovation will be needed to return these facilities or the land they occupy to ORNL for future use in programmatic activities.

Of the identified facilities, 104 have been accepted by DOE’s Office of Environmental Management (DOE-EM) into either the EM40 program or the EM60 program. These programs manage and ultimately dispose of facilities that have exceeded their useful life and that require continual surveillance and maintenance (S&M) to ensure safe shutdown.

The 56 remaining identified assets are currently surplus or are expected to become surplus beyond FY 1999 because of their lack of mission and a continuing trend of declining budgets. Additional ORNL assets are expected to become unusable as a result of obsolescence and deterioration. Of these facilities, 20 are contaminated and appear to meet criteria for transfer to the EM program.

ORNL S&M costs are generally funded through Laboratory or divisional overhead. These costs exceeded $1 million in FY 1999. To comply with the requirements of DOE Order 430.1A, “Life Cycle Asset Management” (October 14, 1998), more than $3.2 million will be required to transfer 20 surplus/excess contaminated facilities to EM beginning in FY 2002. Order 430.1A also notes that the landlord program for a site should fund these costs and calls for the transfer of S&M funding to EM with the transferred facilities. Negotiations are under way to accommodate the transfer of S&M funding to the EM program with these facilities.

Annual requests for funding for these activities are submitted to the Office of Basic Energy Sciences (program KC) in a Field Work Proposal. These costs will continue to grow in the future and will become an increasingly significant burden on overhead if landlord funding is not provided.

Noncontaminated facilities are not eligible for transfer to the EM program. The burden for disposition of these 32 surplus and inactive facilities will fall on Laboratory overhead and/or currently funded programs. This will have a negative impact, in both the short term and the long term, on R&D and/or landlord programs, leading to a decline in research activities and continued infrastructure deterioration.

5.3.2.6 • Energy Management

ORNL's In-House Energy Management (IHEM) program is directed toward saving energy and money, protecting the environment, enhancing the workplace environment, improving operations, and providing leadership in the adoption of new energy technologies. The program has yielded a 17% 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 35,000 fluorescent lamps (40% of the inventory) have been replaced with more efficient lamps; more than 17,000 ballasts have been replaced with more efficient units that do not contain polychlorinated biphenyls (PCBs); and 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. Energy use has dropped an average 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.

In addition, the conversion of the ORNL steam plant from coal to natural gas (see Sect. 5.3.2.4) is expected to save about $1 million per year in operating costs and $8 million in capital funding over 10 years, in addition to avoiding emissions from coal combustion.

ORNL is actively pursuing the completion of IHEM projects and continuing to take advantage of the savings from recently completed IHEM projects. Of 12 IHEM projects in construction at the start of FY 1999, 10 have been completed and closed out. Those 10 completed projects, in combination with previous IHEM projects, have helped ORNL to reduce energy consumption by 3.3% this year compared to the same period last year.

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.

5.3.3 • 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 sensitive unclassified material and information, special nuclear material, 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 and specialized security plans to address both routine operations and contingencies. Programs are in place to ensure physical security (including protective forces), property protection, nuclear material control and accountability, personnel security, information security, and computer and network security. Strategies for protecting site security interests are designed to assure the required levels of protection. Programs are also developed as needed to assess the potential for radiological or toxicological sabotage and mitigate the consequences of such events.

ORNL safeguards and security functions were inspected by the Office of Security Evaluations within DOE's Office of Environment, Safety and Health (DOE-EH) in January 1999. The inspection team conducted an initial site profile of ORNL, reviewing all facets of the site safeguards and security program, including the Security, Nuclear Material Control and Accountability, and Protective Force organizations and the information security and classification functions.

Under a prime contract awarded in September 1999, Wackenhut Services, Inc. (WSI-OR) will provide selected protective security services at DOE's Oak Ridge sites and facilities, including ORNL, beginning in January 2000. Overall management of most major security programs, with the notable exception of the protective force, remains with the site contractors.

ORNL is working with the protective services contractor to ensure proper protection of DOE interests at the Laboratory. The ORNL security staff also partners with ORNL line organizations, customers, and DOE to develop and maintain appropriate, cost-effective security systems and procedures for addressing protection issues.

Relatively little work that must be shielded or protected for reasons of national security is conducted at ORNL. During the planning period, the Laboratory will continue working to ensure that safeguards and security measures are focused where appropriate and to configure security barriers so that they provide the maximum protection with the minimum hindrance to the flow of people, equipment, and material throughout the site.

5.3.3.1 • Intelligence and Counterintelligence

Measures are in place to deter and neutralize foreign or industrial intelligence activities directed at or involving DOE programs, facilities, technology, personnel, unclassified sensitive information, and classified matter 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. Before-travel briefings on what to expect and on personal safety have demonstrated their value on many occasions.

5.3.3.2 • Security Program Management

Security at ORNL is "everyone's business," but certain organizations have key responsibilities. The Office of Laboratory Protection at ORNL has the overall responsibility for providing nuclear materials control and accountability, nuclear materials management, personnel security, physical security, and badging/visitor services to all ORNL organizations and operations. Within the Office of Laboratory Protection, the Security Department is charged with ensuring the efficacy of ORNL's multidimensional security programs to ensure the protection of assets from intentional damage, industrial or other sabotage, misuse, or theft. Functional areas administered by the Security Department are shown in Table 5.5.

The ORNL Computing, Information, and Networking Division has responsibilities in (1) information security and (2) computing and network security. The ORNL Guest Services/ Foreign National Office (an element of the Office of Science and Technology Partnerships, which is in turn part of the ORNL Office of Partnerships and Program Development) assures that all DOE, U.S. Immigration and Naturalization Service, and LMER requirements for access are met for both domestic and foreign national visitors and guests.

These organizations work together to produce a security posture appropriate to ORNL's role as a broadly based, multiprogram laboratory. An internal web page maintained by the Security Department provides security information to ORNL staff members, and a hard-copy newsletter, *Security Insights*, is distributed to all employees on a regular basis.

Table 5.5
Security Department functional areas

Security program management
Facility approval and registration of activities
Foreign ownership, control, or influence (FOCI) program
Security of off-site facilities
Security operations
Safeguards and security planning
Safeguards and security performance testing
Physical security
Security alarm systems
Keys and locks
Thefts, unusual events, incident reporting
Information security
Operations security (OPSEC) program
Personnel security services
DOE access authorization processing (security clearances)
Personnel Security Assurance Program
Security awareness program
Badging and visitor services
Badge reader system interface
Employee badging (oversight of service provided by WSI-OR)
Visitor services

5.3.3.3 • Physical Security

Beginning in January 2000, protective force operations at ORNL will be 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 for the Laboratory through activities that span

- developing programs to protect ORNL's critical infrastructure,
- managing both recurring and contingency security issues,
- developing security plans,
- performing vulnerability analyses,
- formulating cost-efficient and innovative security policies and procedures,
- assuring the availability of adequate resources and systems (keys, locks, security alarms, closed-circuit television, automated portals, badge readers, etc.) for the protection of special nuclear materials (SNM), Laboratory infrastructure, and other government assets entrusted to the care of ORNL personnel,
- assuring the presence of a viable Technical Surveillance Countermeasures (TSCM) Program (see Sect. 5.3.3.7), and
- ensuring the presence of suitable physical measures when storage of classified matter, controlled substances, precious metals, and/or other sensitive items is required.

The physical security team is also responsible for ensuring that both on-site and off-site consequences stemming from the potential for radiological or toxicological sabotage are appropriately assessed and mitigated.

5.3.3.4 • Property Protection

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 the Site Safeguards and 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 Office of Laboratory Protection 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.

5.3.3.5 • Nuclear Material Control and Accountability

The Nuclear Materials Control and Accountability (NMC&A) Department in the ORNL Office of Laboratory Protection is responsible for the management, accountability, control, and planning activities necessary to ensure both optimum safeguards and effective utilization of nuclear materials. The NMC&A Department

- provides control and accountability of nuclear materials, as evidenced by a near-real-time accountability system,
- maintains an approved and comprehensive NMC&A Plan;
- conducts periodic nuclear material internal assessments in each Materials Balance Area in ORNL,
- develops all reports as required in a timely manner, and
- provides an efficient and effective process for management of accountable nuclear materials.

5.3.3.6 • Personnel Security

The Security Department provides oversight of WSI-OR performance of selected personnel security services. These services include DOE access authorization processing (security clearances), an effective safeguards and security awareness program, and the Personnel Security Assurance Program (a DOE-mandated human reliability program designed specifically to reduce "insider" risks to national security). The ORNL Security Department will continue to manage the badge reader system that allows for automated access control of appropriately badged personnel and to process visits to the Laboratory, in each instance verifying the clearance level and need to know of visitors. Coordination with the ORNL Guest Services/Foreign National Office ensures proper management of guests and visitors from other nations.

5.3.3.7 • 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 information security function to ensure appropriate levels of protection against unauthorized access, loss, or compromise of classified matter under the purview of the Laboratory. The ORNL Information Security Officer is a member of this organization. This function also provides 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.

Classification of information is overseen by the ORNL Classification Officer, a member of ORNL's Computing, Information, and Networking Division who also serves as the Laboratory's Technical Information Officer. As Technical Information Officer, this individual also supports the protection of export control information and, in reviewing information, maintains an awareness of intellectual property issues. The ORNL Patent Office, the Office of Technology Transfer, and the Work for Others program also contribute to ensuring the protection and effective management of the Laboratory's intellectual property.

5.3.3.8 • Computer and Network Security

The Computer and Network Security (CNS) organization in ORNL's Computing, Information, and Networking Division is responsible for both unclassified and classified computer security programs at ORNL. 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 Computing, Information, and Networking Division, the Instrumentation and Controls Division, and the designated division computer security officers (DCSOs) within each ORNL division to ensure computer security, including reviews of division computer equipment and systems. An integrated security feature on ORNL's internal web server, called "Doorkeeper," reduces the risk of unauthorized access to access-controlled pages. External computer security events are coordinated with DOE, Lockheed Martin Energy Systems, Inc. (LMES), the LMES Computing and Telecommunications Security Organization, and DOE's Computer Incident Advisory Capability, as needed.

Changes to the ORNL CNS program are communicated through DCSOs and through other information distribution channels (e.g., division offices).

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 Management Organization provides guidance and assistance in export compliance.

5.3.4 • Business Management

ORNL's Business Management Organization provides the Laboratory with services in contract administration, finance and accounting, procurement, property management, small business programs, Work for Others, and business interfaces with Lockheed Martin Energy Systems, Inc. (LMES), the M&O contractor for the Oak Ridge Y-12 Plant. LMES currently provides ORNL with benefits administration and real estate services.

5.3.4.1 • Cost Savings

ORNL continues to seek and implement cost efficiencies as a means of reducing overhead and making more resources available for research. These efforts build on a long-term program of cost reduction that was reinforced by a commitment, made in connection with DOE's Strategic Alignment Initiative, to reduce costs by $18 million per year for five years, beginning in FY 1996. Cost efficiencies arising from reengineering efforts (see Sect. 5.3.4.2), combined with the work of ORNL's Fix-It Committee and individual division efforts, allowed ORNL to meet its $90 million Strategic Alignment Initiative commitment early. Cost efficiencies captured since the initiative began exceed $116 million.

ORNL has reduced its overhead from $170.6 million in FY 1995 to $126.4 million in FY 1999. The overhead rate for FY 1999 was 39.07%, down from 44.9% in FY 1995. A cost savings and avoidance program is conducted in partnership with the DOE ORNL Site Office. The program includes project promotion and identification, project reporting and validation, and progress reports to the DOE ORNL Site Office and DOE-ORO. Further cost reductions will be sought in all areas of operations.

5.3.4.2 • Reengineering

Laboratory-wide reengineering, which began in 1996 shortly after LMER became ORNL's M&O contractor, is aimed at improving the Laboratory's effectiveness in executing its mission assignments and serving its customers. Although the formal reengineering effort was completed in FY 1999, work will continue through the planning period to improve ORNL's ability to carry out its mission assignments, operate safely and efficiently, and function as a leading research institution.

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

Business Systems

ORNL's reengineering of its business systems has centered on implementation of the SAP R/3 enterprise information system (see Sect. 5.2.2.2). SAP R/3 is a highly integrated information system that eliminates the need to maintain and update multiple databases and, over the long term, will reduce the costs required to maintain a number of nonintegrated business systems.

In parallel with the implementation of SAP R/3, new or enhanced automated systems are being used to plan and control cost, reduce redundant systems, and increase efficiency. Examples include the PRISM property management system, which allows equipment custodians and employees to complete most property actions on line, and the Program Management Tracking System, which provides personal computer and workstation users with easy access to budget data. These efforts reflect ORNL's growing use of computer networks as a tool for managing and distributing information (see Sect. 5.2.2.2).

Engineering Design and Construction

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

As recommended by the reengineering team, ORNL established its own Engineering Division and assumed direct responsibility for design contracting and construction management. This approach eliminated several layers of interfaces with the construction management organization, the LMES engineering organization, and DOE.

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

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

The total cost for this reengineering effort was $635,000. Savings for the first five projects undertaken with the new approach exceeded this amount, and the response from R&D staff members was positive. Near-term challenges include working within the Construction Labor Agreement between the Knoxville Building and Construction Trades Council and MK-Ferguson of Oak Ridge and the associated challenge of attracting highly qualified and committed firms to do business at the ORNL site. Another key to achieving cost-effectiveness is adoption of industrial paradigms. The implementation of Work Smart standards is a significant advance toward this end. Efforts continue to improve the understanding of the various relationships between costs and requirements and to work with the accounting systems to highlight anomalous practices.

Environment, Safety, Health, and Quality

Reengineering of ESH&Q functions was undertaken to improve ORNL's performance while reducing the cost of compliance activities. Four objectives were adopted:

1. Maintain a complete set of Work Smart Standards (WSS) that is well understood and used as the framework for all ESH&Q programs.
2. Develop revised ORNL-level ESH&Q procedures to reflect the requirements of the WSS sets and assure effective ESH&Q operations.
3. Implement ESH&Q training programs necessary to support ESH&Q work and compliance.
4. Clarify responsibilities for ESH&Q activities between line and support organizations.

The WSS set, developed using DOE's Necessary and Sufficient process, is now maintained as a "living document." The ESH&Q Reengineering Team identified the need for a system to ensure WSS integrity by (a) avoiding the addition of inappropriate regulations and (b) adding standards as appropriate to address hazards that might arise from new work activities. The ORNL Standards Committee carries out this function in accordance with ORNL-CR-005, "Process for Maintaining and Modifying ORNL Work Smart Standards (WSS)."

ORNL procedures were revised and rewritten to reflect the requirements of the WSS set. The number of procedures was reduced by almost 50%, and procedures are now maintained electronically.

ORNL-TI-001, "ORNL Training Program Description," documents the Laboratory's approach to identifying training requirements and maintaining flexibility to accommodate multiple training sources and delivery systems. The ORNL Training Integration Office guides and coordinates training activities in accord with this directive, and SAP is used to are facilitate the establishment and tracking of training requirements tailored to job assignments.

Each line organization at ORNL has completed a "Responsibility Matrix" with each of the ESH&Q support organizations. These matrices, which are based on a line-by-line review of ESH&Q tasks and define responsibilities for each task, strongly reinforce the ISMS principle of line responsibility.

With the exception of a very few revisions to the ESH&Q directives, the objectives of the ESH&Q reengineering team are complete. Final implementation of some objectives was completed by the ISMS Implementation Committee (see Sect. 5.1.1).

Research Support Services

Research support services at ORNL are provided by the Plant and Equipment (P&E) Division. Reengineering of these services was undertaken with the goal of providing best-in-class services for ORNL.

A 1996 report by the Research Support Services Reengineering Committee identified low productivity as the major hindrance to best-in-class research support services at ORNL and presented five broad recommendations:

- Clarify and adopt a customer service vision.
- Remove specific barriers and improve systems that hinder productivity.
- Improve and consistently use specific behaviors to improve customer service, reduce costs, increase productivity and accountability.
- Redefine roles and responsibilities to emphasize teamwork and customer service.
- Reiterate a renewed commitment to success on the part of all stakeholders.

In implementing these recommendations, division managers and members of the Atomic Trades and Labor Council (ATLC) have worked together, forging a strong union-management partnership and excellent working relationships.

In October 1996, a Reengineering Steering Committee was formed and charged with implementing the reengineering recommendations. Team members represent both division management and ATLC members. The committee, which meets weekly, provides a forum for ongoing dialog and charters ad hoc teams to work specific issues.

The reengineering report identified 65 specific opportunities for improvement. Of these, 32 have been fully implemented, 24 are being worked, and 9 remain unachieved. To date, 11 teams have been chartered to address both the recommendations of the reengineering report and other issues that have arisen since the report was issued.

Major successes in terms of customer service focus include reductions in absenteeism and overtime, both resulting in rate reductions. Advances have been made in removing barriers to productivity, an area in which many items were relatively easy to address. Recommendations on expensed bench stock and better transportation have been fully implemented, leading to much improved availability of commonly used items and vehicles and thus to improvements in craft productivity. Training in leadership skills is in place, and teams are now used at all levels on an ad hoc basis. Participative management practices are now used throughout the P&E Division.

Work continues to reduce costs. Gains in this area may have been masked by the many accounting and business rule changes instituted during the past two years. The P&E Division will also continue its efforts to build the desired “organizational culture,” characterized by customer focus, a high level of trust, sensitivity to competitive forces, total involvement of the work force, and high personal accountability. Dealing with the cultural issues now being addressed is likely to be a frustrating and time-consuming process. The time and emotional investment in the union-management partnership, coupled with the sense of accomplishment gained from successes to date, provide a strong foundations on which to build in addressing these issues.

5.3.5 • Performance-Based Management

The management and operation (M&O) contract between the Department of Energy (DOE) and Lockheed Martin Energy Research Corporation (LMER), which expires on March 31, 2000, provides for the use of performance measurements to promote continuous improvement and provides a basis for evaluating contractor performance. Critical Outcomes and Objectives covering the first half of FY 2000 (see Table 5.6) address six areas: Science and Technology; Leadership; Environment, Safety, and Health; Infrastructure; Business Operations; and Stakeholder Relations. The M&O contract between DOE and UT-Battelle, LLC, which goes into effect on April 1, 2000, also provides for the establishment and evaluation of performance objectives for expectations in these areas.

LMER reports bimonthly achievements toward accomplishment of these Critical Outcomes to DOE’s Oak Ridge Operations Office. An overall assessment report will be provided to the Oak Ridge Operations Office by March 31, 2000.

Table 5.6
Critical outcomes for ORNL
(developed by the Oak Ridge Operations Office)

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

Under the M&O contract between DOE and UT-Battelle, performance objectives will be established prior to April 1, 2000, and subsequently before the beginning of each fiscal year. A Performance Evaluation and Measurement Plan will be prepared to document details related to the definition and evaluation of performance objectives. In addition, UT-Battelle will prepare an annual self-assessment that addresses strengths and weaknesses in performance for review by DOE as part of the evaluation process.

5.3.6 • Quality Programs

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

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

6 • Enterprise Activities

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

6.1 • Science and Technology Partnerships

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

The ORNL Office of Partnerships and Program Development was established in 1998 in response to a recommendation made by the Science and Technology Partnerships Reengineering Team. Components of the organization include the Office of Technology Transfer, the Office of Science and Technology Partnerships (Partnerships Office), and the Work for Others program, as well as ORNL program development staff. Educational activities (see Sect. 6.1.4) are coordinated through the ORNL Office of University and Science Education.

6.1.1 • Collaborative Relationships

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

ORNL will continue to develop and draw on collaborative relationships that support DOE's missions. In particular, ORNL plans to increase its outreach to small and medium-sized businesses, focusing on increasing awareness of cooperative research and technical assistance opportunities available to these firms. These businesses are also good candidates for partnerships under the Small Business Technology Transfer (STTR) Program.

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

6.1.1.1 • Laboratory Partnerships

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

- the National Spherical Torus Experiment, a joint project with the Princeton Plasma Physics Laboratory, Columbia University, and the University of Washington;
- the PHENIX detector for the Relativistic Heavy Ion Collider at Brookhaven;
- the Main Injector Neutrino Oscillation Search (MINOS) experiment at the Fermi National Accelerator Laboratory;
- the Materials Microcharacterization Collaboratory, which provides on-line access to materials science research capabilities, with Argonne, Lawrence Berkeley, the National Institute for Standards and Technology, and the University of Illinois;
- the Genome Annotation Consortium, through which ORNL is working with Argonne, Lawrence Berkeley, Lawrence Livermore, Los Alamos, several universities, and other research institutions to provide a comprehensive sequence-based view of genomes;
- the High Performance Storage System development project, which links Lawrence Berkeley, Lawrence Livermore, Los Alamos, Sandia, and ORNL with industrial partners;
- the DOE 2000 initiative, sponsored by the Office of Advanced Scientific Computing Research within the DOE Office of Science, which is creating and applying computational tools and libraries that advance the concept of "national collaboratories";
- the Energy Efficiency and Renewable Energy Network with Argonne and the National Renewable Energy Laboratory;
- an ORNL-Sandia-Idaho collaboration, initiated through Laboratory Directed R&D funds from each laboratory, that integrates unique capabilities in the development of the Laser-Assisted Arc Welding (LAAW) process; and
- the Interlaboratory Task Force on Unexploded Ordnance, which coordinates the capabilities of 14 DOE laboratories and facilities (see Sect. 6.2.2.2).

6.1.1.2 • University Partnerships

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

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

ORNL and UT are partners in the Science Alliance, the state's oldest and largest academic Center of Excellence. The Science Alliance sponsors the ORNL-UT Distinguished

Scientist Program, which provides joint appointments to tenured positions at UT Knoxville and research positions at ORNL. Graduate programs and joint institutes in biological sciences, computational sciences, energy and environment, heavy ion research, and neutron sciences represent additional tools for combining the resources of these institutions for research and education. The National Transportation Research Center, described in Sect. 3.4.6, is providing new opportunities for collaboration.

ORNL has established a Memorandum of Cooperation with UT, Vanderbilt University Medical Center, St. Jude Children's Research Hospital, and Meharry Medical College (an HBCU) for collaborative research in developing mouse models for human diseases. This arrangement is the result of an initiative undertaken through the Joint Institute for Biological Sciences (see Sect. 4.2.6).

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

Nearly 150 representatives from the state's six HBCUs (Fisk University, Knoxville College, Lane College, LeMoyne-Owen College, Meharry Medical College, and Tennessee State University) attended ORNL's first Tennessee Historically Black Colleges and Universities Day in April 1999. The event was designed to acquaint students and faculty at these institutions with ORNL research staff and their programs, with the aim of encouraging increased interactions.

ORNL has also established a mentoring project with Tennessee State University (TSU). The Chief Financial Officer (CFO) Mentor Project brings a TSU business student to ORNL for an internship project that provides an overview of ORNL's financial systems and operations. The project was suggested by the manager of the ORNL Small Business Program Office as a means of strengthening relationships between HBCUs/MEIs and the Laboratory.

6.1.1.3 • Industry Partnerships

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

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

The Partnerships Office is also working to encourage more interaction with small businesses. Much of this activity is expected to occur in the technical assistance area, with support from the Laboratory Technology Research assistance program. During FY 1999, ORNL assisted 31 small businesses.

Cooperative partnerships with industry continue to be an attractive mechanism for affording access to ORNL's scientific resources and skills. The leveraging of research dollars through cost sharing is beneficial to both parties. ORNL's cumulative total for cooperative R&D agreements (CRADAs) is 291 (not including joint ORNL/Y-12 projects), representing commitments of more than $500 million. As DOE funding for CRADAs has decreased over the past five years, the number of private partners directly funding collaborative R&D has increased. In FY 1999, the contract value of new collaborative R&D funds reached a record $14 million.

The American Textile Partnership (AMTEX), a collaborative program involving ten DOE laboratories and the U.S. textile industry, has engaged the technical capabilities of the laboratories in developing and deploying technologies that will increase the competitiveness of this industry. The Partnership for a New Generation of Vehicles (PNGV) has supported cooperative projects involving programs in DOE's Offices of Science, Energy Efficiency and Renewable Energy (DOE-EE), and Defense Programs. ORNL is pursuing the implementation of partnerships with companies and consortia representing the industries participating in the DOE-EE Industries of the Future initiative (see Sect. 2.4.4.2).

6.1.2 • Guests and Users

Guest scientists are a valuable component of ORNL's research staff. Their assignments, which range from two weeks to two years, broaden the Laboratory's base of expertise and support goals in scientific cooperation and technology transfer. In FY 1999, the Partnership Office supported approximately 3000 assignments of scientists and engineers from universities, industries, and other federal institutions. About 25% were industrial guests. More than 1000 of these guests conducted R&D at one of ORNL's designated user facilities.

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. Almost 200 new agreements were signed in FY 1999.

6.1.3 • Technology Transfer

The Office of Technology Transfer manages and protects ORNL's intellectual property, leveraging this intellectual property to increase its value through partnerships with the private sector and licensing it to large and small businesses to promote the commercialization of innovations based on DOE programmatic R&D. 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. In FY 1999, 128 patents were issued (compared with 53 in FY 1998), 15 licenses were executed, and 31 new CRADAs were established.

6.1.4 • Science Education

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

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

Science education programs make extensive use of partnerships with a wide variety of other organizations. For example, a grant from the U.S. Department of Education supports the development of Internet-based learning materials. The project brings teachers from Tennessee, Virginia, South Carolina, and New York to ORNL to participate in the development and testing of an Internet tutorial about energy. ORNL and the Oak Ridge Institute for Science and Education co-sponsor an annual Women in Science and Technology Conference for high school and college students. The annual summer SciCops camp, conducted in collaboration with the Knox County Sheriff's Department, introduces middle-school students to the role of science in law enforcement. ORNL works with the Appalachian Regional Commission to offer a Summer Science Honors Academy and a Teacher Leadership Institute to students and teachers from Appalachian states.

During the planning period, ORNL will continue to seek opportunities to apply its resources to educating the next generation of scientists and engineers and to improving scientific and technological literacy. The addition of the American Museum of Science and Energy (AMSE) to ORNL's scope of work (see Sect. 5.2.1) is providing new opportunities in these areas. For example, ORNL and AMSE staff recently worked together to bring an exhibit sponsored by the American Ceramics Society to the museum. Exhibit development included the preparation of teaching materials for use in the Ecological and Physical Sciences Study Center.

6.2 • Developing Strengths for Mission Needs

6.2.1 • Laboratory Directed R&D

The Laboratory Directed R&D (LDRD) Program described in Sect. 2.4.4.7 provides a means of funding activities that are expected to enhance ORNL's capabilities for carrying out DOE missions. In requesting proposals for FY 2000 Director's R&D funds, the Laboratory's senior managers have selected research topics associated with the four major Laboratory initiatives (see Sect. 4) as target areas and nanoscale science, technology, and engineering as a special emphasis area. The selection of these areas reflects ORNL's commitment to managing discretionary resources for strategic change.

6.2.1.1 • 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 the SNS and the HFIR upgrade (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:

- advanced neutron optics,
- data visualization and analysis,
- novel instrumentation concepts,
- novel applications of neutron scattering, and
- neutron physics.

6.2.1.2 • Complex Biological Systems

ORNL's Complex Biological Systems Initiative (see Sect. 4.2) engages organizations and disciplines across the Laboratory in addressing the complex interactions, pathways, balances, and control mechanisms of biological systems and builds on established programs and expertise in the life sciences; on innovative application of computational, physical, chemical, and engineering sciences to biology; and on special facilities and resources in analytical technologies. LDRD projects in this area will address one or more of the following:

- the development of a comparative systems biology that leads to better use and integration of information from different model organisms;
- the definition and development of good model "complex pathways" or specific biological processes, in any organism, that can serve as unique and tractable systems for future dissection and study;
- in vitro and whole-organism approaches for complex pathway analysis;
- identification and definition of some of the components of selected complex pathways for analysis with new technologies;
- genetic and molecular approaches to identifying gene-product interactions in networks and temporal changes in the functional roles of specific gene products;
- integrated genomic approaches to analyze metabolic pathways, regulatory networks, cellular processes, and relationships between organisms and environments;
- analytical technologies that provide simultaneous information on multiple metabolic steps and provide analysis at the single-cell level; and
- mathematical modeling of checks and balances in known pathways.

6.2.1.3 • Terascale Computing and Simulation Science

The major Laboratory initiative in terascale computing and simulation science (see Sect. 4.3) will expand ORNL's ability to support DOE's missions by accelerating the integration of simulation, modeling, and computation into the Laboratory's R&D programs. LDRD projects will address one or more of the following research areas:

- simulation science,
- massively parallel computing,
- distributed computing, and
- virtual laboratories.

6.2.1.4 • Energy and Environmental Systems of the Future

ORNL's Energy and Environmental Systems of the Future (E^2SF) initiative (see Sect. 4.4) is aimed at developing a comprehensive and systematic approach to meeting the growing global need for energy services. To support the E^2SF initiative, ORNL will fund innovative research that is expected to yield scientific advances and technology innovations in

- understanding the geological, chemical, material, biological, and physical processes that underpin the discovery, production, distribution, and use of energy, and exploiting this understanding in the development of clean and affordable energy;
- understanding the molecular, atmospheric, geological, ecological, and biological effects of energy use and energy byproducts on the biosphere; and
- providing integrating capabilities in systems analysis to support the development and deployment of systems for the safe, reliable, and efficient production, generation, storage, and distribution of energy.

6.2.1.5 • Nanoscale Science, Engineering, and Technology

The identification of nanoscale science, engineering, and technology as a special emphasis area for LDRD funding recognizes a worldwide explosion of nanoscale science and engineering knowledge, in which some ORNL staff are already participating, and positions ORNL for broader participation in this field, which is expected to become increasingly important to advances in areas of interest to DOE, such as materials, manufacturing, energy and environment, information technology, global competitiveness, and national security.

Nanoscience is concerned with discovering, understanding, characterizing, and fabricating novel properties, phenomena, and processes that occur in materials and systems primarily because of their small size. 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 materials properties and to create functional devices with greatly improved or entirely new functions.

LDRD funding will support the discovery and development of fundamental knowledge and skills and the acquisition of critical tools and capabilities, in order to strategically position the Laboratory for leadership in nanoscale R&D. The following themes have been identified:

- discovery of novel phenomena and processes;
- controlled synthesis and processing, including (1) nanoscale precursors for macro-structures and devices and (2) assembly mechanisms for macrostructures and devices;
- novel concepts for nanosensors and nanodevices;
- hybrid nanosystems and devices that integrate functionalities;
- nanoscale instrumentation (new tools and methods for nanoscale properties measure-ments and manipulation);

- applications (nanosensors and nanomachines); and
- infrastructure and facilities needs (focusing on integrated facilities and the development of core enabling technologies).

Modeling and simulation are an integral part of much of this work.

6.2.2 • Program Development Activities

6.2.2.1 • Overview

Program development activities at ORNL are focused on maintaining the R&D expertise available to DOE and on identifying and pursuing new opportunities to apply the Laboratory's strengths to mission-related needs. These activities serve to broaden ORNL's customer base and provide opportunities for partnerships with universities, industry, other DOE laboratories, other federal agencies, and state and regional organizations. They often draw on the resources available throughout DOE's Oak Ridge Complex.

Program development is carried out by individual researchers, by program development staff within ORNL divisions, by ORNL managers, and by staff in ORNL's Office of Partnerships and Program Development. The Office of Partnerships and Program Development coordinates activities related to the development of new programs and provides key services dealing with intellectual property and partnerships.

During the planning period, increasing emphasis will be placed on creating synergy and sharing knowledge among program developers and on identifying opportunities in emerging areas, such as gene function and biotechnology, and in areas that represent pressing national needs, such as transportation and environmental protection. ORNL also plans to continue its emphasis on offsite assignments of staff members, which provide opportunities for integration of ORNL staff into other government agencies and for learning more about the private sector.

The Office of Partnerships and Program Development directs its efforts toward key customers within DOE, at other federal agencies, and in the private sector and toward the application of Laboratory strengths in specific areas, such as biotechnology. Efforts are coordinated with Lockheed Martin Energy Systems, Inc. (LMES); the deputy director of the LMES National Security Programs Office (NSPO) and the ORNL co-leader of the Oak Ridge Centers for Manufacturing Technology (ORCMT) at the Oak Ridge Y-12 Plant also report to the Office of Partnerships and Program Development. Staff also work closely with the DOE Oak Ridge Operations Office (DOE-ORO) Office of Partnerships and Program Development.

6.2.2.2 • Areas of Emphasis

Defense Advanced Research Projects Agency

The Defense Advanced Research Projects Agency (DARPA) is the central science and technology agency of the U.S. Department of Defense (DOD). DARPA supports the development of high-risk, high-payoff technologies and advanced military concepts needed to keep the United States secure. ORNL strengths in materials, biotechnology, microelectromechanical systems, robotics, sensors, and computation are well matched to DARPA's needs. In FY 1998, ORNL involvement with DARPA included 15 projects, representing funding of more than $3 million per year distributed across 10 divisions. During the planning period, ORNL will continue its efforts to identify new opportunities and improve support to DARPA by providing an increased presence at the agency and expanding the awareness of DARPA needs at the Laboratory.

U.S. Department of Defense

Development of new programs to support the U.S. Department of Defense (DOD) is guided by a strategic plan produced in FY 1998, which outlines a strategy of focusing on selected areas that match customer needs with Laboratory strengths; focusing on larger ($1 million to $5 million), multidisciplinary programs; looking “over the horizon” (a decade or more ahead); and targeting key customers within DOD and related defense and national security agencies. Work is under way to expand existing programs and to develop new initiatives.

Ongoing programs include (1) the development of advanced materials for protecting combat vehicles and personnel and for improving the structure and survivability of ground vehicles, helicopters, and aircraft; (2) the development of instrumentation and smart sensors for detection of chemical/biological agents, unexploded ordnance (UXO), and terrorist threats and for diagnostics that support equipment maintenance and life extension; and (3) environmental analysis and management for environmental compliance, cleanup, and management of military sites and for safe dismantling and decommissioning of weapons systems.

Initiatives currently being pursued include

- the 21st Century Truck Partnership, which links DOD, DOE, the U.S. Department of Transportation, and the Environmental Protection Agency with truck manufacturers, power train manufacturers, and academia;
- hybrid electric/diesel-powered combat vehicles;
- logistics modernization, with the aim of reducing the logistics demand for military operations; and
- environmentally safe management of military lands and disposal of defense material stockpiles, including UXO.

The area of UXO detection and disposal represents a serious and costly challenge for the United States and other nations. A joint DOD-DOE program, aimed at finding new means of detecting, defeating, and removing UXO, draws on resources coordinated by the Interlaboratory UXO Task Force, which was initiated in 1997 by ORNL and Sandia National Laboratories and now involves some 14 DOE facilities and numerous university and industrial partners. ORNL is exploring remote sensing from aerial vehicles and developing computer programs that use remotely collected data to develop images and signatures of concealed ordnance. In work for the Defense Threat Reduction Agency (DTRA), ORNL has also demonstrated that genetically engineered light-emitting bacteria can signal the presence of hidden explosives, offering a potentially cost-effective and safe way of locating anti-personnel mines over a wide area.

National Aeronautics and Space Administration

ORNL is exploring new opportunities to apply its strengths to the needs of the National Aeronautics and Space Administration (NASA). NASA’s Human Exploration and Development of Space (HEDS) enterprise (formerly, the Space Exploration Program) at the Johnson Space Center in Houston, Texas, 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 NASA's 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.

Biotechnology

Biotechnology—broadly defined as the development and application of living organisms or biological techniques to meet human needs in such areas as agriculture, environmental protection, and medicine—will be a key technology for the 21st century. Dramatic advances in the ability to understand, emulate, and modify the functioning of biological systems; to determine how natural materials are constructed; and to observe and manipulate materials at the molecular scale are leading to new applications for biotechnology in such areas as environmental remediation, pollution abatement, national security, and energy production.

ORNL's extensive strengths in biotechnology draw on its diversity of disciplinary foundations (e.g., biochemistry, bioengineering, biomaterials, biophysics, computational sciences, chemistry, ecology, medical imaging, molecular and structural biology) and its distinctive capabilities in biological and environmental sciences and technology. These resources support a variety of work; for example, the Complex Biological Systems Initiative (see Sect. 4.2) draws on these integrated resources. ORNL is one of several DOE laboratories participating in the Biotechnology Interlaboratory Council, which was established in recognition of the emerging importance of biotechnology, the magnitude of the laboratories' collective efforts, and the synergistic value of linking their capabilities.

ORNL plans to emphasize three key areas in biotechnology: chemical and biological defense, biomaterials and biomimetics, and biomedical applications. These areas serve established and growing markets, take advantage of substantial ORNL capabilities, and draw on expertise and facilities in several ORNL divisions and directorates. The ORNL Center for Biotechnology provides a coordinated focus for these activities.

Chemical and Biological Defense • Concern about chemical and biological weapons is increasing in both the military and domestic communities, with a growing demand for new means of detecting, preventing, and responding to acts of terrorism using such weapons. ORNL has established direct relationships with the Chem-Bio Defense Directorate and the Counterproliferation organization of DTRA and with DOE's liaison to DTRA to facilitate the application of Laboratory capabilities to needs in this area. Increased interaction with the U.S. Army Soldier and Biological Chemical Command and the U.S. Army Edgewood Research, Development, and Engineering Center will also be pursued during the planning period.

Substantial funds have been identified for developing "first responder" capabilities, and major gaps in capabilities, which provide niches for research, have been identified. A June 1998 seminar at ORNL, presented by Dr. James Hansen (LTC Ret.), who developed the U.S. Joint Services Biodefense Program, focused on identifying gaps in response that could be addressed with ORNL capabilities. Several major areas, including decontamination, detection/avoidance, and emergency management, were identified.

Decontamination—of equipment, facilities, or the environment—requires the ability to detect and measure contaminants and to manage events during and after decontamination. ORNL will continue to work with DOD organizations involved in decontamination research and will maintain a structured relationship with outside consultants who work closely with DOD and DOE to help increase the Laboratory's participation in detection, exposure reduction, incident management, salvage of equipment and materials, site restoration, and management of residual contamination.

The threat of terrorist attacks using chemical or biological agents has heightened attention to emergency management, an area in which ORNL has substantial expertise. ORNL hosted a May 1999 workshop for the Federal Emergency Management Agency, DOE, and DOD and is leading an Oak Ridge Complex effort to integrate and apply capabilities for addressing both natural and man-made disasters.

Biomaterials and Biomimetics • Biomaterials and biomimetics represent a broad field of research that has been identified as a growth area for ORNL—an area in which the Laboratory's expertise in materials science and in biotechnology can be leveraged to develop new R&D programs that address emerging needs. Several potential sponsors of new work in this area have been identified, and directed efforts to introduce Laboratory researchers to these sponsors have already produced $3 million to $4 million in new funding for ORNL over the next three years. Work will continue to build on recent successes through sponsor identification, "bridge-building" among ORNL divisions and other research units, and dissemination of information to attract new sponsors, raise the interest of ORNL staff, and promote the development of new research endeavors.

Biomedical Applications • ORNL's long-standing expertise in biomedical applications was most recently recognized with the presentation of an R&D 100 award to a team of Laboratory researchers for the multifunctional biochip, which integrates microelectronics and biotechnology in a biological sensor that provides for rapid screening and detection of diseases. Such advanced medical measurement tools represent a probable area of growth.

ORNL will focus its efforts on conducting an inventory of existing capabilities and activities, identifying emerging opportunities (drawing on external expertise as appropriate), and forming cross-organizational teams to promote shared knowledge and improve working relationships. Linkages to the Virtual Human effort (see Sect. 3.4.7) will be explored.

National Safety and Security

ORNL capabilities are broadly applicable to needs in national safety and security. In addition to work for DOD, DARPA, and other military entities, ORNL has supported the National Institute of Justice, the Federal Bureau of Investigation, and law enforcement agencies with its expertise in chemistry, biology and computing. The Office of Partnerships and Program Development plans to explore additional opportunities with these and other sponsors.

7 • Resource Projections

Resource projections are presented in the following tables:

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

These projections are based on funding requested in the FY 2000 budget submission documents, with some adjustments for subsequent guidance. They include some funding for construction that supports the major laboratory initiatives proposed in Sect. 4.

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

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

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

	1998	1999	2000	2001	2002	2003	2004
DOE effort	492.5	545.8	407.8	433.0	416.2	411.1	415.6
Work for others	83.4	75.4	90.0	92.5	94.5	97.0	100.0
Total operating	575.9	621.2	497.8	525.5	510.7	508.1	515.6
Capital equipment	12.0	17.4	16.7	14.0	11.5	8.8	8.8
Capital equipment, SNS	0.1	0.5	0.9	1.3	1.9	0.0	0.0
General Plant Equipment (GPE)	4.3	3.3	3.3	3.3	3.3	3.3	3.3
Construction	1.9	10.0	6.9	8.9	4.5	4.5	4.5
Total ORNL	594.2	652.4	525.6	553.0	531.9	524.7	532.2
Proposed construction	—	101.4	198.8	277.6	279.9	200.7	78.9
Total projected funding	—	753.8	724.4	830.6	811.8	725.4	611.1

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

	1998	1999	2000	2001	2002	2003	2004
Technical personnel, direct DOE effort	1366.8	1580.6	1554.5	1567.0	1555.5	1552.1	1552.2
Technical personnel, Work for Others	294.3	335.1	374.6	386.6	386.6	386.6	386.6
Total technical direct personnel	1661.1	1915.7	1929.1	1953.6	1942.1	1938.7	1938.8
Other direct	678.4	457.1	374.9	421.7	418.5	417.2	418.1
Total direct personnel	2339.5	2372.8	2304.0	2375.3	2360.6	2355.9	2356.9
Indirect personnel (estimated)	2035.5	2065.9	1984.1	1919.1	1919.1	1919.1	1919.1
Total ORNL personnel	4375.0	4438.7	4288.1	4294.4	4279.7	4275.0	4276.0

Table 7.3
Funding by assistant secretarial level office by fiscal year

($ in millions—BA)

	1998	1999	2000	2001	2002	2003	2004
Science and Technology Programs							
Office of Science							
Operating expense	170.8	172.6	164.1	159.6	157.3	158.3	167.0
Capital equipment	7.3	13.7	13.5	11.1	10.1	7.4	7.4
Capital equipment (SNS)	0.1	0.5	0.9	1.3	1.9	0.0	0.0
General Plant Equipment (GPE)	4.3	3.3	3.3	3.3	3.3	3.3	3.3
Construction	0.3	12.6	6.9	8.9	4.5	4.5	4.5
Proposed construction	0.0	101.4	198.8	277.6	279.9	200.7	78.9
Total	182.8	304.1	387.5	461.8	457.0	374.2	261.1
Energy Programs							
Office of Energy Efficiency and Renewable Energy							
Operating expense	86.0	105.9	91.0	99.2	100.2	101.8	103.0
Capital equipment	0.9	1.8	0.6	0.6	0.6	0.6	0.6
Construction	0.0	(0.6)	0.0	0.0	0.0	0.0	0.0
Total	86.9	107.1	91.6	99.8	100.8	102.4	103.6
Office of Nuclear Energy, Science and Technology							
Operating expense	15.1	16.9	16.6	18.9	17.9	17.9	17.9
Capital equipment	0.4	0.0	0.2	0.2	0.2	0.2	0.2
Total	15.5	16.9	16.8	19.1	18.1	18.1	18.1
Office of Fossil Energy							
Operating expense	8.3	10.4	11.3	11.6	11.6	12.0	12.0
Energy Information Administration							
Operating expense	0.0	0.0	0.0	0.0	0.0	0.0	0.0
National Security Programs							
Office of Defense Programs							
Operating expense	17.4	20,1	15.9	19.0	18.1	18.1	18.1
Capital equipment	1.2	0.0	2.1	1.9	0.4	0.4	0.4
Construction	1.6	(2.0)	0.0	0.0	0.0	0.0	0.0
Total	20.2	18.1	18.0	20.9	18.5	18.5	18.5
Office of Nonproliferation and National Security							
Operating expense	0.1	1.7	(0.4)	0.6	0.6	0.6	0.6
Office of Fissile Materials Disposition							
Operating expense	13.7	19.6	17.5	32.9	36.1	35.8	35.3
Environmental Management Programs							
Office of Environmental Management[a]							
Operating expense	34.7	28.9	17.5	16.0	15.0	15.0	15.0
Capital equipment	2.2	1.9	0.3	0.2	0.2	0.2	0.2
Total	36.9	30.8	17.8	16.2	15.2	15.2	15.2
Office of Civilian Radioactive Waste Management							
Operating expense	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Office of Environment, Safety, and Health							
Operating expense	6.4	3.2	2.0	2.2	2.2	2.2	2.2

Table 7.3
(continued)

	1998	1999	2000	2001	2002	2003	2004
Other DOE Programs							
Office of Policy							
Operating expense	0.4	0.3	0.3	0.5	0.5	0.5	0.5
Office of Chief Financial Officer							
Operating expense	0.1	1.5	(0.1)	0.0	0.0	0.0	0.0
Office of Worker and Community Transition							
Operating expense	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Federal Energy Regulatory Commission							
Operating expense	1.4	0.5	0.5	0.5	0.5	0.5	0.5
EM funding from LMES central financial plan and Bechtel Jacobs Co.							
Operating expense	78.5	65.4	10.5	14.0	7.7	4.4	4.0
Subtotal DOE Programs							
Operating expense	433.0	447.1	346.7	375.0	367.7	367.1	376.1
Capital equipment	12.0	17.4	16.7	14.0	11.5	8.8	8.8
Capital equipment (SNS)	0.1	0.5	0.9	1.3	1.9	0.0	0.0
General Plant Equipment (GPE)	4.3	3.3	3.3	3.3	3.3	3.3	3.3
Construction	1.9	10.0	6.9	8.9	4.5	4.5	4.5
Proposed construction	0.0	101.4	198.8	277.6	279.9	200.7	78.9
Total	451.3	579.7	573.3	680.1	668.8	584.4	471.6
DOE Contractors and Operations Offices							
Operating expense	57.7	94.6	58.6	55.5	46.0	41.0	36.5
Cooperative R&D Agreements							
Operating expense	1.8	4.1	2.5	2.5	2.5	3.0	3.0
Total DOE Programs							
Operating expense	492.5	545.8	407.8	433.0	416.2	411.1	415.8
Capital equipment	12.0	17.4	16.7	14.0	11.5	8.8	8.8
Capital equipment (SNS)	0.1	0.5	0.9	1.3	1.9	0.0	0.0
General Plant Equipment (GPE)	4.3	3.3	3.3	3.3	3.3	3.3	3.3
Construction	1.9	10.0	6.9	8.9	4.5	4.5	4.5
Proposed construction	0.0	101.4	198.8	283.4	274.1	199.5	78.9
Total	510.8	678.4	634.4	738.1	717.3	628.4	511.1
Work for others							
Nuclear Regulatory Commission							
Operating expense	10.8	10.0	10.0	10.0	10.0	10.0	10.0
Department of Defense							
Operating expense	26.0	27.0	28.0	28.5	29.0	30.0	31.0
National Aeronautics and Space Administration							
Operating expense	3.6	4.2	5.8	5.7	5.7	5.7	5.7
Department of Health and Human Services							
Operating expense	2.4	1.6	3.4	3.4	3.4	3.4	3.4

Table 7.3
(continued)

	1998	1999	2000	2001	2002	2003	2004
Environmental Protection Agency							
Operating expense	5.5	2.4	3.4	3.4	3.4	3.4	3.4
National Science Foundation							
Operating expense	0.2	0.1	0.0	0.0	0.0	0.0	0.0
Federal Emergency Management Agency							
Operating expense	2.6	2.5	2.0	2.0	2.0	2.0	2.0
Department of Transportation							
Operating expense	6.5	10.2	10.8	11.9	11.9	11.9	11.9
Other Federal agencies							
Operating expense	10.7	2.1	10.7	10.8	11.1	11.5	12.5
Electric Power Research Institute							
Operating expense	1.1	0.8	0.6	0.2	0.2	0.2	0.2
Other nonfederal agencies							
Operating expense	14.0	14.5	15.3	16.6	17.8	18.9	19.9
Total Work for Others							
Operating expense	83.4	75.4	90.0	92.5	94.5	97.0	100.0
Total ORNL							
Operating expense	575.9	621.2	497.8	525.5	510.7	508.1	515.6
Capital equipment	12.0	17.4	16.7	14.0	11.5	8.8	8.8
Capital equipment, SNS	0.1	0.5	0.9	1.3	1.9	0.0	0.0
General Plant Equipment (GPE)	4.3	3.3	3.3	3.3	3.3	3.3	3.3
Construction	1.9	10.0	6.9	8.9	4.5	4.5	4.5
Proposed construction	0.0	101.4	198.8	277.6	279.9	200.7	78.9
Total	594.2	753.8	724.4	830.6	811.8	725.4	611.1

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

Table 7.4
Personnel by assistant secretarial level office by fiscal year
[Full-time equivalent (FTE) employees]

	1998	1999	2000	2001	2002	2003	2004
Office of Science							
Technical personnel	477.6	578.8	589.8	666.6	666.6	666.6	676.1
Other direct personnel	171.9	208.8	196.7	261.0	261.0	261.0	263.6
Total direct personnel	649.5	787.6	786.5	927.6	927.6	927.6	939.7
Office of Energy Efficiency and Renewable Energy							
Technical personnel	196.6	272.9	266.7	267.1	267.1	267.1	267.1
Other direct personnel	55.1	29.7	26.9	28.8	28.8	28.8	28.8
Total direct personnel	251.7	302.6	293.6	295.9	295.9	295.9	295.9
Office of Nuclear Energy, Science and Technology							
Technical personnel	50.4	61.0	71.0	59.4	59.4	59.4	59.4
Other direct personnel	28.9	14.0	13.4	11.3	11.3	11.3	11.3
Total direct personnel	79.3	75.0	84.4	70.7	70.7	70.7	70.7
Office of Fossil Energy							
Technical personnel	19.9	30.0	30.6	30.8	30.8	30.8	30.8
Other direct personnel	6.1	3.9	1.8	1.0	1.0	1.0	1.0
Total direct personnel	26.0	33.9	32.4	31.8	31.8	31.8	31.8
Energy Information Administration							
Technical personnel	0.1	0.2	0.2	0.1	0.1	0.1	0.1
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	0.1	0.2	0.2	0.1	0.1	0.1	0.1
Office of Defense Programs							
Technical personnel	46.9	61.0	59.1	59.5	59.5	59.5	59.5
Other direct personnel	25.2	32.2	30.6	32.6	32.6	32.6	32.6
Total direct personnel	72.1	93.2	89.7	92.1	92.1	92.1	92.1
Office of Nonproliferation and National Security							
Technical personnel	0.0	3.4	0.0	0.0	0.0	0.0	0.0
Other direct personnel	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	0.1	3.4	0.0	0.0	0.0	0.0	0.0
Office of Fissile Materials Disposition							
Technical personnel	36.1	36.2	59.2	66.7	66.7	66.7	66.7
Other direct personnel	10.4	0.5	0.5	0.5	0.5	0.5	0.5
Total direct personnel	46.5	36.7	59.7	67.2	67.2	67.2	67.2
Office of Environmental Management							
Technical personnel	74.3	81.3	53.2	39.2	39.2	39.2	39.2
Other direct personnel	14.9	25.3	14.3	9.3	9.3	9.3	9.3
Total direct personnel	89.2	106.6	67.5	48.5	48.5	48.5	48.5
Office of Civilian Radioactive Waste Management							
Technical personnel	0.1	0.3	0.3	0.3	0.3	0.3	0.3
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	0.1	0.3	0.3	0.3	0.3	0.3	0.3
Office of Environment, Safety, and Health							
Technical personnel	14.1	16.0	13.7	11.3	11.3	11.3	11.3
Other direct personnel	2.9	3.2	2.0	1.7	1.7	1.7	1.7
Total direct personnel	17.0	19.2	15.7	13.0	13.0	13.0	13.0

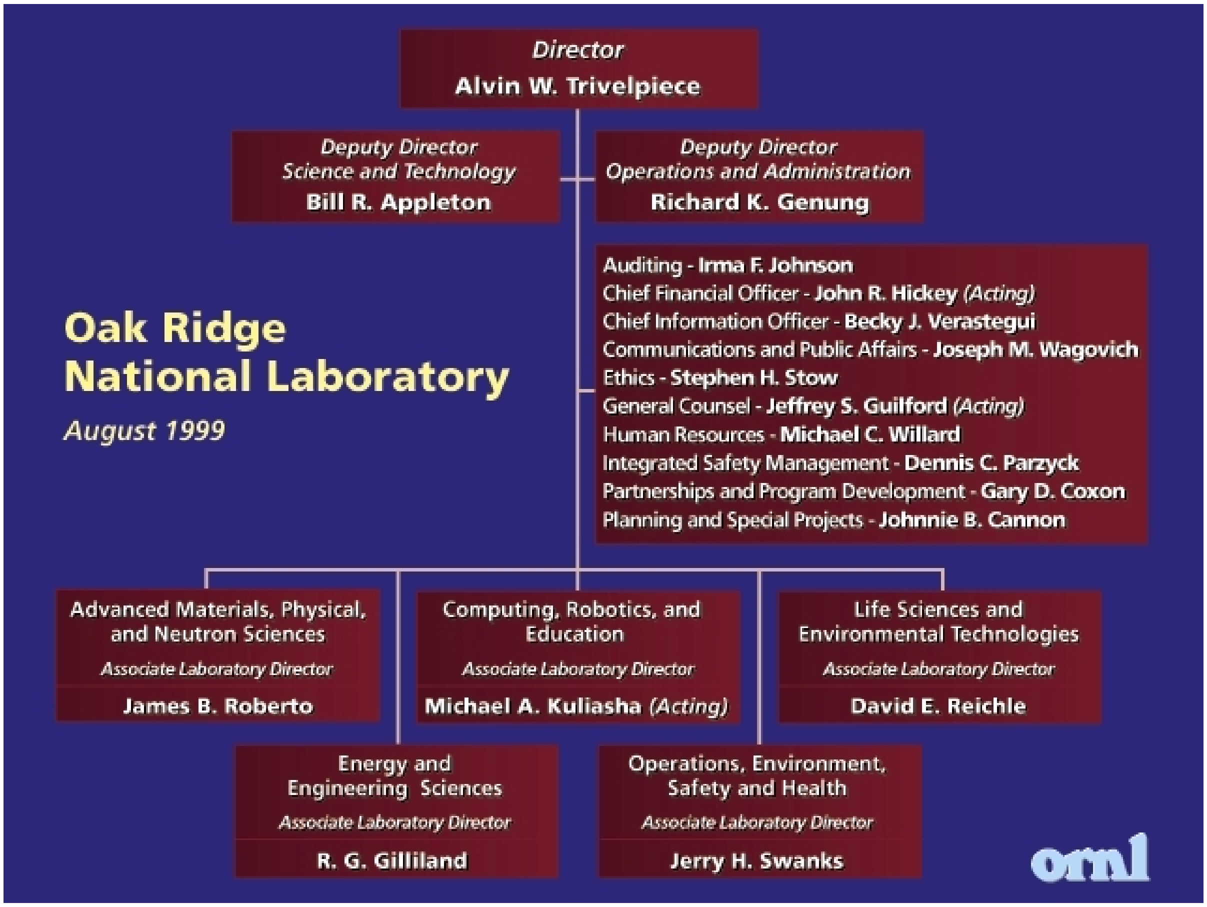
Table 7.4
(continued)

	1998	1999	2000	2001	2002	2003	2004
Office of Policy							
Technical personnel	1.5	0.9	0.5	0.4	0.4	0.4	0.4
Other direct personnel	0.6	0.0	0.1	0.1	0.1	0.1	0.1
Total direct personnel	2.1	0.9	0.6	0.5	0.5	0.5	0.5
Office of Worker and Community Transition							
Technical personnel	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Federal Energy Regulatory Commission							
Technical personnel	2.8	4.2	2.6	0.0	0.0	0.0	0.0
Other direct personnel	0.3	0.2	0.2	0.0	0.0	0.0	0.0
Total direct personnel	3.1	4.4	2.8	0.0	0.0	0.0	0.0
EM funding from LMES central financial plan and Bechtel Jacobs Co.							
Technical personnel	120.0	101.3	73.7	60.4	48.9	45.5	36.1
Other direct personnel	282.2	55.9	26.0	10.7	7.5	6.2	4.5
Total direct personnel	402.2	157.2	99.7	71.1	56.4	51.7	40.6
Subtotal DOE Programs							
Technical personnel	1040.5	1247.5	1218.5	1261.8	1250.3	1246.9	1247.0
Other direct personnel	598.6	373.7	312.5	357.0	353.8	352.5	353.4
Total direct personnel	1639.1	1621.2	1531.0	1618.8	1604.1	1599.4	1600.4
DOE Contractors and Operations Office							
Technical personnel	320.6	316.4	323.0	297.3	297.3	297.3	297.3
Other direct personnel	24.2	23.1	19.7	26.0	26.0	26.0	26.0
Total direct personnel	344.8	339.5	342.7	323.3	323.3	323.3	323.3
Cooperative R&D Agreements							
Technical personnel	5.7	16.7	13.0	7.9	7.9	7.9	7.9
Other direct personnel	0.9	0.6	0.0	0.0	0.0	0.0	0.0
Total direct personnel	6.6	17.3	13.0	7.9	7.9	7.9	7.9
Total DOE Programs							
Technical personnel	1366.8	1580.6	1554.5	1567.0	1555.5	1552.1	1552.2
Other direct personnel	623.7	397.4	332.2	383.0	379.8	378.5	379.4
Total direct personnel	1990.5	1978.0	1886.7	1950.0	1935.3	1930.6	1931.6
Work for others							
Nuclear Regulatory Commission							
Technical personnel	46.3	54.2	58.3	59.4	59.4	59.4	59.4
Other direct personnel	8.5	7.1	2.2	0.5	0.5	0.5	0.5
Total direct personnel	54.8	61.3	60.5	59.9	59.9	59.9	59.9
Department of Defense							
Technical personnel	87.8	89.6	105.4	106.5	106.5	106.5	106.5
Other direct personnel	10.0	12.5	8.0	9.4	9.4	9.4	9.4
Total direct personnel	97.8	102.1	113.4	115.9	115.9	115.9	115.9
National Aeronautics and Space Administration							
Technical personnel	12.1	10.7	13.3	14.7	14.7	14.7	14.7
Other direct personnel	1.7	8.6	7.1	5.9	5.9	5.9	5.9
Total direct personnel	13.8	19.3	20.4	20.6	20.6	20.6	20.6

Table 7.4
(continued)

	1998	1999	2000	2001	2002	2003	2004
Department of Health and Human Services							
Technical personnel	13.9	13.8	11.5	10.8	10.8	10.8	10.8
Other direct personnel	17.1	17.0	16.0	15.0	15.0	15.0	15.0
Total direct personnel	31.0	30.8	27.5	25.8	25.8	25.8	25.8
Environmental Protection Agency							
Technical personnel	20.2	19.6	16.0	14.2	14.2	14.2	14.2
Other direct personnel	0.4	0.4	0.1	0.0	0.0	0.0	0.0
Total direct personnel	20.6	20.0	16.1	14.2	14.2	14.2	14.2
National Science Foundation							
Technical personnel	2.0	2.0	1.5	0.0	0.0	0.0	0.0
Other direct personnel	1.0	1.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	3.0	3.0	1.5	0.0	0.0	0.0	0.0
Federal Emergency Management Agency							
Technical personnel	6.5	6.5	5.0	5.0	5.0	5.0	5.0
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	6.5	6.5	5.0	5.0	5.0	5.0	5.0
Department of Transportation							
Technical personnel	22.2	45.5	45.8	42.0	42.0	42.0	42.0
Other direct personnel	7.0	3.1	2.8	2.8	2.8	2.8	2.8
Total direct personnel	29.2	48.6	48.6	44.8	44.8	44.8	44.8
Other Federal agencies							
Technical personnel	7.6	17.0	43.6	53.5	53.5	53.5	53.5
Other direct personnel	1.1	1.1	1.5	1.0	1.0	1.0	1.0
Total direct personnel	8.7	18.1	45.1	54.5	54.5	54.5	54.5
Electric Power Research Institute							
Technical personnel	5.7	4.2	1.8	0.7	0.7	0.7	0.7
Other direct personnel	1.0	1.0	0.4	0.4	0.4	0.4	0.4
Total direct personnel	6.7	5.2	2.2	1.1	1.1	1.1	1.1
Other nonfederal agencies							
Technical personnel	70.0	72.0	72.4	79.8	79.8	79.8	79.8
Other direct personnel	6.9	7.9	4.6	3.7	3.7	3.7	3.7
Total direct personnel	76.9	79.9	77.0	83.5	83.5	83.5	83.5
Total Work for Others							
Technical personnel	294.3	335.1	374.6	386.6	386.6	386.6	386.6
Other direct personnel	54.7	59.7	42.7	38.7	38.7	38.7	38.7
Total direct personnel	349.0	394.8	417.3	425.3	425.3	425.3	425.3
Total ORNL							
Technical personnel	1661.1	1915.7	1929.1	1953.6	1942.1	1938.7	1938.8
Other direct personnel	678.4	457.1	374.9	421.7	418.5	417.2	418.1
Total ORNL direct personnel	2339.5	2372.8	2304.0	2375.3	2360.6	2355.9	2356.9
Total ORNL indirect personnel	2035.5	2065.9	1984.1	1919.1	1919.1	1919.1	1919.1
Total ORNL personnel	4375.0	4438.7	4288.1	4294.4	4279.7	4275.0	4276.0

Appendix A
Laboratory Organization Chart


Director
Alvin W. Trivelpiece
Deputy Director
Science and Technology
Bill R. Appleton
Deputy Director
Operations and Administration
Richard K. Genung
Auditing - Irma F. Johnson
Chief Financial Officer - John R. Hickey (Acting)
Chief Information Officer - Becky J. Verastegui
Communications and Public Affairs - Joseph M. Wagovich
Ethics - Stephen H. Stow
General Counsel - Jeffrey S. Guilford (Acting)
Human Resources - Michael C. Willard
Integrated Safety Management - Dennis C. Parzyck
Partnerships and Program Development - Gary D. Coxon
Planning and Special Projects - Johnnie B. Cannon
Oak Ridge
National Laboratory
August 1999
Advanced Materials, Physical, and Neutron Sciences
Associate Laboratory Director
James B. Roberto
Computing, Robotics, and Education
Associate Laboratory Director
Michael A. Kuliasha (Acting)
Life Sciences and Environmental Technologies
Associate Laboratory Director
David E. Reichle
Energy and Engineering Sciences
Associate Laboratory Director
R. G. Gilliland
Operations, Environment, Safety and Health
Associate Laboratory Director
Jerry H. Swanks
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Appendix B
Supplemental Information

Table B.1 presents projected resources by program. The projections in Table B.1 are based on funding requested in the FY 2000 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 B.2 and B.3 present information about ORNL's staff. Table B.4 presents estimates for subcontracting and procurement, reported as total obligated funds for each fiscal year, and Table B.5 presents estimates for small and disadvantaged business procurement.

Table B.6 provides details on the use of ORNL's designated user facilities during FY 1998. Table B.7 provides details on participants in ORNL's university and science education programs.

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

	1998	1999	2000	2001	2002	2003	2004
Office of Science							
Magnetic Fusion—AT							
Total operating	17.7	17.8	16.0	16.2	16.1	16.1	16.1
Capital equipment	0.2	0.3	0.2	0.2	0.2	0.2	0.2
Total program	17.9	18.1	16.2	16.4	16.3	16.3	16.3
High Energy Physics—KA							
Total operating	0.7	0.2	0.2	0.2	0.2	0.2	0.2
Capital equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total program	0.7	0.2	0.2	0.2	0.2	0.2	0.2
Nuclear Physics—KB							
Total operating	13.8	13.6	13.2	14.0	14.0	14.0	14.0
Capital equipment	2.0	2.1	2.0	2.0	2.0	2.0	2.0
Construction	0.4	0.4	0.0	0.0	0.0	0.0	0.0
Proposed construction	0.0	0.0	0.6	0.6	0.6	0.6	0.6
Total program	16.2	16.1	15.8	16.6	16.6	16.6	16.6
Basic Energy Sciences—KC[a]							
Total operating	90.2	99.9	87.7	87.1	84.7	85.1	93.6
Capital equipment	4.3	3.4	4.0	4.0	4.0	4.0	4.0
Capital equipment, SNS	0.1	0.5	0.9	1.3	1.9	0.0	0.0
General plant equipment (GPE)	4.3	3.3	3.3	3.3	3.3	3.3	3.3
Construction	0.0	4.7	4.5	4.5	4.5	4.5	4.5
Proposed construction, SNS	0.0	101.4	196.1	267.9	262.5	193.6	78.3
Total program	98.9	213.2	296.5	368.1	360.9	290.5	183.7
Compliance—KC03							
Total operating	3.2	2.4	6.0	1.4	0.0	0.0	0.0
Capital equipment	0.0	4.6	2.3	3.9	2.7	0.0	0.0
Construction	0.0	0.7	2.4	4.4	0.0	0.0	0.0
Total program	3.2	7.7	10.7	9.7	2.7	0.0	0.0
Energy Research Analyses—KD							
Total operating	0.8	0.0	1.0	0.6	0.6	0.6	0.6
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)	(0.1)	6.9	0.0	0.0	0.0	0.0	0.0
Proposed construction	0.0	0.0	2.1	6.6	6.8	5.1	0.0
Total program	(0.1)	6.9	2.1	6.6	6.8	5.1	0.0
Computational and Technology Research—KJ							
Total operating	19.1	11.8	15.6	15.4	17.0	17.1	16.8
Capital equipment	0.3	1.5	0.5	0.5	0.7	0.7	0.7
Total program	19.4	13.3	16.1	15.9	17.7	17.8	17.5
Biological and Environmental Research—KP							
Total operating	25.0	26.2	23.6	24.0	24.0	24.5	25.0
Capital equipment	0.5	1.8	4.5	0.5	0.5	0.5	0.5
Proposed construction	0.0	0.0	0.0	2.5	10.0	1.4	0.0
Total program	25.5	28.0	28.1	27.0	34.5	26.4	25.5
Office of Science Program Direction—KX							
Total operating	0.3	0.7	0.8	0.7	0.7	0.7	0.7

Table B.1
(continued)

	1998	1999	2000	2001	2002	2003	2004
Total Office of Science							
Operating expense	170.8	172.6	164.1	159.6	157.3	158.3	167.0
Capital equipment	7.3	13.7	13.5	11.1	10.1	7.4	7.4
Capital equipment, SNS	0.1	0.5	0.9	1.3	1.9	0.0	0.0
General plant equipment (GPE)	4.3	3.3	3.3	3.3	3.3	3.3	3.3
Construction	0.3	12.6	6.9	8.9	4.5	4.5	4.5
Proposed construction	0.0	101.4	198.8	277.6	279.9	200.7	78.9
Total program	182.8	304.1	387.5	461.8	457.0	374.2	261.1
Office of Energy Efficiency and Renewable Energy							
Solar and Renewable Resource Technologies—EB							
Total operating	18.4	18.4	16.9	19.1	19.6	20.0	20.0
Capital equipment	0.2	0.5	0.1	0.1	0.1	0.1	0.1
Total program	18.6	18.9	17.0	19.2	19.7	20.1	20.1
Buildings Sector—EC							
Total operating	18.7	19.5	18.3	19.6	20.1	20.8	22.0
Capital equipment	0.0	0.3	0.2	0.2	0.2	0.2	0.2
Total program	18.7	19.8	18.5	19.8	20.3	21.0	22.2
Industrial Sector—ED							
Total operating	15.1	26.3	16.6	20.5	20.5	21.0	21.0
Transportation Sector—EE							
Total operating	32.2	39.0	37.1	38.0	38.0	38.0	38.0
Capital equipment	0.7	1.0	0.3	0.3	0.3	0.3	0.3
Total program	32.9	40.0	37.4	38.3	38.3	38.3	38.3
Policy and Management—EH							
Total operating	0.6	0.9	0.5	0.6	0.6	0.6	0.6
Utility Sector—EK							
Total operating	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Federal Energy Management Program—EL							
Total operating	1.0	1.8	1.7	1.4	1.4	1.4	1.4
In-House Energy Management—WB							
Operating expense	0.0	0.0	(0.1)	0.0	0.0	0.0	0.0
Construction	0.0	(0.6)	0.0	0.0	0.0	0.0	0.0
Total program	0.0	(0.6)	(0.1)	0.0	0.0	0.0	0.0
Total Office of Energy Efficiency and Renewable Energy							
Operating expense	86.0	105.9	91.0	99.2	100.2	101.8	103.0
Capital equipment	0.9	1.8	0.6	0.6	0.6	0.6	0.6
Construction	0.0	(0.6)	0.0	0.0	0.0	0.0	0.0
Total program	86.9	107.1	91.6	99.8	100.8	102.4	103.6

Table B.1
(continued)

	1998	1999	2000	2001	2002	2003	2004
Office of Nuclear Energy, Science and Technology							
Nuclear Energy R&D—AF							
Total operating	4.3	5.5	5.8	5.3	5.3	5.3	5.3
Capital equipment	0.0	0.0	0.1	0.1	0.1	0.1	0.1
Total program	4.3	5.5	5.9	5.4	5.4	5.4	5.4
Naval Reactors—AJ							
Total operating	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Uranium Enrichment—CD							
Total operating	0.0	0.1	(0.1)	0.0	0.0	0.0	0.0
Policy and Management—KK							
Total operating	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Isotope Production and Distribution Program—ST							
Total operating	10.7	11.1	10.8	13.5	12.5	12.5	12.5
Capital equipment	0.4	0.0	0.1	0.1	0.1	0.1	0.1
Total program	11.1	11.1	10.9	13.6	12.6	12.6	12.6
Total Office of Nuclear Energy, Science and Technology							
Operating expense	15.1	16.9	16.6	18.9	17.9	17.9	17.9
Capital equipment	0.4	0.0	0.2	0.2	0.2	0.2	0.2
Total program	15.5	16.9	16.8	19.1	18.1	18.1	18.1
Office of Fossil Energy							
Coal—AA							
Total operating	4.5	4.6	6.1	6.0	6.0	6.0	6.0
Gas—AB							
Total operating	1.9	3.0	1.6	1.8	1.8	1.8	1.8
Petroleum—AC							
Total operating	1.7	2.5	3.2	3.6	3.6	4.0	4.0
Fossil Energy Environmental Restoration—AW							
Total operating	0.0	0.1	0.1	0.0	0.0	0.0	0.0
Innovative Clean Coal Technology—AZ							
Total operating	0.1	0.0	0.1	0.0	0.0	0.0	0.0
Strategic Petroleum Reserve—SA							
Total operating	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Total Office of Fossil Energy							
Total operating	8.3	10.4	11.3	11.6	11.6	12.0	12.0
Energy Information Administration							
National Energy Information System—TA							
Total operating	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Energy Information Administration							
Total operating	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table B.1
(continued)

	1998	1999	2000	2001	2002	2003	2004
Office of Defense Programs							
Weapons Activities—DP							
Total operating	17.4	20.1	15.9	19.0	18.1	18.1	18.1
Capital equipment	1.2	0.0	2.1	1.9	0.4	0.4	0.4
Construction	1.6	(2.0)	0.0	0.0	0.0	0.0	0.0
Total program	20.2	18.1	18.0	20.9	18.5	18.5	18.5
Total Office of Defense Programs							
Total operating	17.4	20.1	15.9	19.0	18.1	18.1	18.1
Capital equipment	1.2	0.0	2.1	1.9	0.4	0.4	0.4
Proposed construction	1.6	(2.0)	0.0	0.0	0.0	0.0	0.0
Total program	20.2	18.1	18.0	20.9	18.5	18.5	18.5
Office of Nonproliferation and National Security							
Counterintelligence—CN							
Total operating	0.0	1.4	(0.3)	0.6	0.6	0.6	0.6
Arms Control and Nonproliferation—GJ							
Total operating	0.0	0.3	(0.1)	0.0	0.0	0.0	0.0
Emergency Management—ND							
Total operating	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total Office of Nonproliferation and National Security							
Total operating	0.1	1.7	(0.4)	0.6	0.6	0.6	0.6
Office of Fissile Materials Disposition							
Fissile Materials Disposition—GA							
Total operating	13.7	19.6	17.5	32.9	36.1	35.8	35.3
Total Office of Fissile Material Disposition							
Total operating	13.7	19.6	17.5	32.9	36.1	35.8	35.3
Office of Environmental Management							
Environmental Management—EM (in ORNL Financial Plan)[b]							
Total operating	34.7	28.9	17.5	16.0	15.0	15.0	15.0
Capital equipment	2.2	1.9	0.3	0.2	0.2	0.2	0.2
Total program	36.9	30.8	17.8	16.2	15.2	15.2	15.2
Total Office of Environmental Management							
Total operating	34.7	28.9	17.5	16.0	15.0	15.0	15.0
Capital equipment	2.2	1.9	0.3	0.2	0.2	0.2	0.2
Total program	36.9	30.8	17.8	16.2	15.2	15.2	15.2
Office of Civilian Radioactive Waste Management							
Nuclear Waste Fund—DF							
Total operating	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Total Office of Civilian Radioactive Waste Management							
Total operating	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Office of Environment, Safety and Health							
Environment, Safety, and Health (Non-Defense)—HC							
Total operating	6.2	3.0	1.8	2.0	2.0	2.0	2.0
Environment, Safety, and Health (Defense)—HD							
Total operating	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Total Office of Environment, Safety and Health							
Total operating	6.4	3.2	2.0	2.2	2.2	2.2	2.2

Table B.1
(continued)

	1998	1999	2000	2001	2002	2003	2004
Office of Policy							
Emergency Planning—NC							
Total operating	0.0	0.0	0.0	0.1	0.1	0.1	0.1
Policy, Analysis, and Systems Studies—PE							
Total operating	0.4	0.3	0.3	0.4	0.4	0.4	0.4
Total Office of Policy							
Total operating	0.4	0.3	0.3	0.5	0.5	0.5	0.5
Office of Chief Financial Officer							
Pollution Prevention—86							
Total operating	0.1	0.2	0.0	0.0	0.0	0.0	0.0
Oak Ridge Landlord—AH (Museum)							
Total operating	0.0	1.3	(0.1)	0.0	0.0	0.0	0.0
Total Office of Chief Financial Officer							
Total operating	0.1	1.5	(0.1)	0.0	0.0	0.0	0.0
Office of Worker and Community Transition							
Worker and Community Transition Program—CG							
Total operating	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total Office of Worker and Community Transition							
Total operating	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Federal Energy Regulatory Commission							
Federal Energy Regulatory Commission—VR							
Total operating	1.4	0.5	0.5	0.5	0.5	0.5	0.5
Total Federal Energy Regulatory Commission							
Total operating	1.4	0.5	0.5	0.5	0.5	0.5	0.5
Environmental Management (Central Financial Plan and Bechtel Jacobs Co.)							
Total operating	78.5	65.4	10.5	14.0	7.7	4.4	4.0
Subtotal DOE Programs							
Operating expense	433.0	447.1	346.7	375.0	367.7	367.1	376.1
Capital equipment	12.0	17.4	16.7	14.0	11.5	8.8	8.8
Capital equipment (SNS)	0.1	0.5	0.9	1.3	1.9	0.0	0.0
General Plant Equipment (GPE)	4.3	3.3	3.3	3.3	3.3	3.3	3.3
Construction	1.9	10.0	6.9	8.9	4.5	4.5	4.5
Proposed construction	0.0	101.4	198.8	277.6	279.9	200.7	78.9
Total	451.3	579.7	573.3	680.1	668.8	584.4	471.6
DOE Contractors and Operations Offices							
Total operating	57.7	94.6	58.6	55.5	46.0	41.0	36.5
Cooperative R&D Agreements							
Total operating	1.8	4.1	2.5	2.5	2.5	3.0	3.0

Table B.1
(continued)

	1998	1999	2000	2001	2002	2003	2004
Total DOE Programs							
Operating expense	492.5	545.8	407.8	433.0	416.2	411.1	415.6
Capital equipment	12.0	17.4	16.7	14.0	11.5	8.8	8.8
Capital equipment (SNS)	0.1	0.5	0.9	1.3	1.9	0.0	0.0
General Plant Equipment (GPE)	4.3	3.3	3.3	3.3	3.3	3.3	3.3
Construction	1.9	10.0	6.9	8.9	4.5	4.5	4.5
Proposed construction	0.0	101.4	198.8	277.6	279.9	200.7	78.9
Total	510.8	678.4	634.4	738.1	717.3	628.4	511.1
Work for others							
Nuclear Regulatory Commission							
Operating expense	10.8	10.0	10.0	10.0	10.0	10.0	10.0
Department of Defense							
Operating expense	26.0	27.0	28.0	28.5	29.0	30.0	31.0
National Aeronautics and Space Administration							
Operating expense	3.6	4.2	5.8	5.7	5.7	5.7	5.7
Department of Health and Human Services							
Operating expense	2.4	1.6	3.4	3.4	3.4	3.4	3.4
Environmental Protection Agency							
Operating expense	5.5	2.4	3.4	3.4	3.4	3.4	3.4
National Science Foundation							
Operating expense	0.2	0.1	0.0	0.0	0.0	0.0	0.0
Federal Emergency Management Agency							
Operating expense	2.6	2.5	2.0	2.0	2.0	2.0	2.0
Department of Transportation							
Operating expense	6.5	10.2	10.8	11.9	11.9	11.9	11.9
Other Federal agencies							
Total operating	10.7	2.1	10.7	10.8	11.1	11.5	12.5
Electric Power Research Institute							
Operating expense	1.1	0.8	0.6	0.2	0.2	0.2	0.2
Other nonfederal agencies							
Total operating	14.0	14.5	15.3	16.6	17.8	18.9	19.9
Total Work for Others							
Total operating	83.4	75.4	90.0	92.5	94.5	97.0	100.0
Total Program Resources							
Operating expense	575.9	621.2	497.8	525.5	510.7	508.1	515.6
Capital equipment	12.0	17.4	16.7	14.0	11.5	8.8	8.8
Capital equipment (SNS)	0.1	0.5	0.9	1.3	1.9	0.0	0.0
General Plant Equipment (GPE)	4.3	3.3	3.3	3.3	3.3	3.3	3.3
Construction	1.9	10.0	6.9	8.9	4.5	4.5	4.5
Proposed construction	0.0	101.4	198.8	277.6	279.9	200.7	78.9
Total	594.2	753.8	724.4	830.6	811.8	725.4	611.1

[a]Estimates for Program KC reflect capital/construction estimates for the Spallation Neutron Source (SNS) beginning in FY 1999.

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

Table B.2
Equal Employment Opportunity statistics for 1998

Occupational code	Total (%)[a]		Minority total (%)		White (%)		Black (%)		Hispanic (%)		Native American (%)		Asian/Pacific Islander (%)	
	M[b]	F[c]	M	F	M	F	M	F	M	F	M	F	M	F
Officials and managers[d]	397 (88.8)	50 (11.2)	27 (6.0)	3 (0.7)	370 (82.8)	47 (10.5)	23 (5.1)	3 (0.7)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	4 (0.9)	0 (0.0)
Professional staff[e]														
Scientists/ engineers	1270 (88.1)	171 (11.9)	127 (8.8)	24 (1.7)	1143 (79.3)	147 (10.2)	30 (2.1)	9 (0.6)	20 (1.4)	0 (0.0)	1 (0.1)	1 (0.1)	76 (5.3)	14 (1.0)
Administra- tive	182 (47.4)	202 (52.6)	18 (4.7)	23 (6.0)	164 (42.7)	179 (46.6)	8 (2.1)	15 (3.9)	5 (1.3)	2 (0.5)	0 (0.0)	0 (0.0)	5 (1.3)	6 (1.6)
Other pro- fessional	192 (73.3)	70 (26.7)	14 (5.3)	7 (2.7)	178 (67.9)	63 (24.0)	12 (4.6)	4 (1.5)	1 (0.4)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.4)	3 (1.1)
Technicians	278 (66.8)	138 (33.2)	21 (5.0)	12 (2.9)	257 (61.8)	126 (30.3)	15 (3.6)	9 (2.2)	5 (1.2)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.2)	3 (0.7)
Clerical	11 (1.8)	587 (98.2)	3 (0.5)	69 (11.5)	8 (1.3)	518 (86.6)	3 (0.5)	58 (9.7)	0 (0.0)	6 (1.0)	0 (0.0)	1 (0.2)	0 (0.0)	4 (0.7)
Crafts/ laborers	703 (91.7)	64 (8.3)	71 (9.3)	14 (1.8)	632 (82.4)	50 (6.5)	67 (8.7)	13 (1.7)	1 (0.1)	0 (0.0)	0 (0.0)	1 (0.1)	3 (0.4)	0 (0.0)
Service workers	60 (65.9)	31 (34.1)	10 (11.0)	13 (14.3)	50 (54.9)	18 (19.8)	10 (11.0)	10 (11.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (1.1)	0 (0.0)	2 (2.2)
Total	3093 (70.2)	1313 (29.8)	291 (6.6)	165 (3.7)	2802 (63.6)	1148 (26.1)	168 (3.8)	121 (2.7)	32 (0.7)	8 (0.2)	1 (<0.1)	4 (0.1)	90 (2.0)	32 (0.7)

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

Table B.3
ORNL staff composition (as of December 31, 1998)[a]

	Ph.D.	M.S.	B.S./B.A.	Other	Total
Professional staff					
Scientists	517	325	287	145	1274
Engineers	255	254	196	119	824
Management/administrative	98	119	110	131	458
Support staff					
Technicians	0	7	92	303	402
All other	0	4	92	1319	1415
Total ORNL staff	870	709	777	2017	4373

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

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

	1998[a]	1999[a]	2000	2001
Universities	20.7	19.9	18.5	18.0
All others	152.4	155.5	131.6	128.0
Transfers to other DOE facilities	1.2	3.2	2.2	2.2
Total external subcontracts and procurements	174.3	178.6	152.3	148.2

[a]Actual.

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

	1998	1999
Total small and disadvantaged business procurement, in millions of dollars	89.3	76.9
Small and disadvantaged business procurement as a percentage of total procurement	51%	43%

Table B.6

Experimenters at ORNL's designated user facilities in FY 1998

	U.S. government laboratory[a]		University		Industry		International[b]		Total		
	Exp.[c]	Org.[c]	Exp.	Org.	Exp.	Org.	Exp.	Org.	Exp.	Org.	User days
Bioprocessing R&D Center	11	4	5	3	9	4	0	0	25	11	46
Buildings Technology Center	31	4	3	3	4	4	3	3	41	14	300
Californium User Facility for Neutron Sciences	0	0	3	2	2	2	2	1	7	5	50
Computational Center for Industrial Innovation	34	7	18	4	34	17	10	6	96	34	197
EN Tandem Van de Graaff	7	1	0	0	0	0	4	4	11	5	4
High Temperature Materials Lab.	5	4	59	43	55	36	0	0	119	83	13,391
Holifield Radioactive Ion Beam Facility	20	2	52	12	0	0	21	9	93	23	336
Metals Processing Laboratory User Center	21	1	6	3	53	40	1	1	81	45	629
Metrology R&D Laboratory	2,983	4	0	0	3	3	0	0	2,986	7	835
Neutron Scattering Research Facilities at HFIR	68	19	42	20	8	5	23	14	141	58	2,395
Oak Ridge Electron Linear Accelerator	0	0	1	1	1	1	2	2	4	4	6
Oak Ridge National Environmental Research Park[d]	43	2	47	20	0	0	1	1	91	23	3,985
Shared Research Equipment Program	41	5	40	25	5	5	2	2	88	37	2,475
Surface Modification and Characterization Research Center	35	1	46	15	5	3	2	2	88	21	4,366
Total	3,299	54	322	151	179	120	71	45	3,871	370	29,015

[a]Includes 3,224 ORNL users (98% of use).
[b]Users from international organizations, regardless of citizenship.
[c]Exp. = number of experimenters; Org. = number of organizations. University entries do not include undergraduate students, if any.
[d]Does not include more than 6,500 individuals who participated in the Ecological and Physical Sciences Study Center.

Table B.7
University and science education

	FY 1998		
	Total	Minor-ities	Women
Precollege student programs			
Adventures in Supercomputing	648	135	252
ARC Honors Academy	36	1	17
Project SEED/Hispanic SEED	3	1	1
Saturday Academy of Computing and Mathematics	15	1	1
Special Honors Study	3	0	0
SciCops Camp	25	5	7
Science Explorers Camp	48	5	5
Ecological and Physical Sciences Study Center	6,002	*a*	*a*
Women in Science and Technology	48	*a*	48
Precollege teacher programs			
Academy for Teachers of Science and Mathematics	47	12	14
Adventures in Supercomputing	48	2	27
ARC Teacher Leadership Institute	24	0	12
Internet Tutorial Project	9	2	3
NTEP II Elementary Science Leadership Institute	4	0	2
Teacher Research Participation	3	0	2
Women in Science and Technology	12	3	12
Undergraduate programs			
Energy Research Undergraduate Laboratory Fellowships	70	12	25
Great Lakes Colleges Association/ Associated Colleges of the Midwest Science Semester	17	5	8
Professional Internship Program	39	0	21
Science and Engineering Research Semester, Summer Program	23	2	11
Student Research Participation Program	64	16	29
Technology Internship Program	4	0	2
Graduate programs			
Graduate Student Research Participation Program	3	0	0
Professional Internship Programs	41	7	16
Research Travel Contracts	3	2	1
Postgraduate programs			
DOE Postdoctoral Programs	102	38	15
Postgraduate Research Training Program	19	4	7
Faculty programs			
Faculty Research Participation	21	2	3
Great Lakes Colleges Association/Associated Colleges of the Midwest	2	0	0
HBCU Faculty Research	13	11	0
Research Travel Contract Visits	3	0	0

[a]Not tracked.

Appendix C
Laboratory Profile

The Laboratory Profile that appears in this appendix was prepared in response to a request from the Department of Energy's Laboratory Operations Board. It is presented here at the direction of the Office of Laboratory Policy. Most of the information in the Laboratory Profile can be found elsewhere in the Institutional Plan. Financial data in the Laboratory Profile are for FY 1998. They were prepared by Department of Energy Headquarters staff and differ from those appearing in Sect. 7 and Appendix B of the Institutional Plan because of differences in definitions and requirements.

Oak Ridge National Laboratory

Laboratory Information

Location: Oak Ridge, Tennessee
Number of Full-Time Employees: 4,453
Scientific and Technical Degrees: 877 Ph.D.'s, 1,448 Bachelor's/Master's
Contractor: Lockheed Martin Energy Research Corp.
Accountable Program Office: Science
Field Office: Oak Ridge Operations
Web Site: http://www.ornl.gov/

Funding Sources

Science: $184.6 million
Energy Efficiency and Renewable Energy: $87.0 million
Environmental Management: $39.6 million
Defense Programs: $27.8 million
Nuclear Energy: $15.6 million
Fissile Materials Disposition: $13.7 million
Other DOE: $16.6 million
Non-DOE: $105.6 million

Total funding: $491.4 million

Note: Budget data shown are for FY98 and exclude remediatioon (cleanup) funds

Description

The Oak Ridge National Laboratory is a multiprogram science, technology, and energy laboratory with strengths in materials science and engineering, neutron science and technology, energy production and end-use technologies, mammalian genetics, and ecological research. Oak Ridge draws on unique facilities in applying these strengths to critical questions about global energy and environmental issues. Neutrons from the High Flux Isotope Reactor support isotope production and materials research and development. The Spallation Neutron Source (under construction) will extend the nation's capabilities for determining the structure of materials. Fundamental nuclear properties and astrophysics are explored with radioactive ion beams. Other research facilities support the integration of basic and applied research, leading to new tools and techniques for clean and efficient energy production, better understanding of complex biological systems, and the relationship between genetics and health, and increased ability to determine and mitigate the environmental effects of energy use. Established in 1942, Oak Ridge developed strengths in nuclear science and engineering, materials research and development, and radiation biology to fulfill its wartime mission.

Distinctive Competencies and Major Facilities

The Laboratory's distinctive competencies are distributed in six major areas: Advanced Materials Synthesis, Characterization, and Processing; Biological and Environmental Sciences and Technology; Computational Science and Advanced Computing; Energy Production and End-Use Technologies; Instrumentation and Measurement Science and Technology; and Neutron-Based Science and Technology. Major facilities include the following:

— The **High Flux Isotope Reactor** is one of the world's most powerful research reactors, with unique capabilities for producing radioisotopes and facilities for materials irradiation, neutron activation analysis, and neutron scattering research; the associated Radiochemical Engineering Development Center offers facilities for producing transuranium actinide elements.

— The **Holifield Radioactive Ion Beam Facility** supplies new information on nuclear properties and supports advances in the understanding of novas, supernovas, X-ray bursts, and other stellar explosions.

— The **Mouse Genetics Research Facility** applies ORNL expertise in mutagenesis and genomics to extensive stocks of mutant mice to advance the understanding of the complex mechanisms underlying the development and functioning of biological systems.

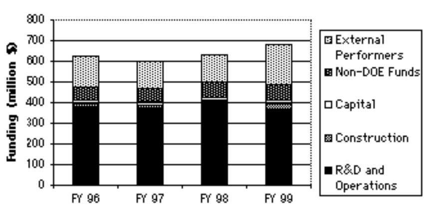
— Materials research facilities include the **High Temperature Materials Laboratory**, supporting collaborative research on advanced ceramics and alloys, the **Surface Modification and Characterization Research Center** for fundamental studies of ion-solid interactions and ion beam processing for advanced thin-film science and technology; and the microanalytical facilities available through the **Shared Research Equipment Program**.

— The **Oak Ridge National Environmental Research Park** contains specialized facilities for large-scale environmental process research.

— The **Buildings Technology Center** supports research on building thermal envelope systems and materials.

— Construction began in FY 99 on the **Spallation Neutron Source,** a collaborative effort of five Departmental Laboratories.

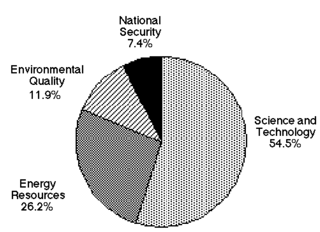
Funding by Activity



Note: Site remediation funds excluded

DOE R&D Footprint

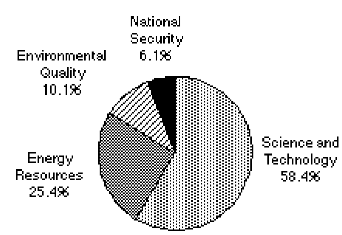
Total R&D: $385.8 million



Note: Based on FY98 funding data; contributing non-DOE funds included; site remediation funds excluded.

DOE Mission Footprint

Total Mission: $491.4 million



Note: Based on FY98 funding data; contributing non-DOE funds included; site remediation funds excluded.

Oak Ridge National Laboratory

Key Research and Development Activities

Science and Technology Mission

The Laboratory's research and development in science and technology supports the delivery of the scientific advances and technical innovations that enable the Department to carry out its missions.

- The Laboratory conducts research and development for the Department in basic energy sciences, biological and environmental research, fusion energy sciences, nuclear physics, computational and technology research, and high-energy physics. Activities span the following fields:
  - Materials science and engineering: Emphasizing development of ceramics and composites, metals and alloys, surfaces and thin films, polymers, superconductors, and new techniques for materials processing and characterization.
  - Analytical and separations chemistry and chemical sciences: Chemical process fundamentals, chemical measurements and instrumentation, environmental monitoring and technology, hydrothermal solution chemistry and geochemistry, interface and surface science, materials chemistry, mass spectrometry research and applications, radioactive materials characterization and actinide science.
  - Environmental and social sciences: Biogeochemistry, environmental biotechnology, global environmental chemistry, ecosystem studies, geosciences, hydrology, environmental assessment, support for planning and policy decisions related to major energy and environmental issues
  - Plasma science and fusion technology.
  - Instrumentation and measurement science and technology.
  - Nuclear physics and high-energy nuclear astrophysics with radioactive ion beams.
  - Neutron science: Neutron scattering, isotope production, and design of accelerator-based and reactor-based neutron sources.
  - Functional genomics, proteomics, biotechnology, and bioengineering.
  - High-performance computing: Computer and computational science, distributed computing, and informatics.
- Major initiatives are aimed at securing new capabilities for answering critical science questions.
  - Neutron science: Construction of the Spallation Neutron Source and upgrades of the High Flux Isotope Reactor should lead to advances in chemistry, magnetism and superconductivity, materials, structural biology, and engineering.
  - Functional genomics: The Laboratory's mutant mouse stocks, expertise in genetics, and strengths in analytical technologies, bioinformatics, and computational biology are combined to explore the structure, organization, and function of genetic material.
  - Teraflops computing and simulation science: Continuing development, integration, and application of computational capabilities and evaluation of an innovative supercomputer will provide the Department with expanded capabilities in scientific simulation.
- The Laboratory's capabilities in crystal growth, isotope research and development and production, and separations science and chemical processing sustain the nation's science and technology enterprise.
- Coordinated programs apply the Laboratory's science and technology resources to national needs in such areas as biotechnology, global climate science and technology, collaborative technologies, and the disposal of unexploded ordnance.

Energy Resources Mission

The Laboratory's in-house energy programs span basic and applied research, technology development, technical assistance, and management of energy-related information. These programs link the physical, engineering, 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:

- Biofuels, with a focus on renewable energy feedstock and conversion technologies
- Energy-efficient technologies for buildings, industrial, transportation, and utility end-use
- Fossil energy, emphasizing applied materials and turbines
- Nuclear technology and safety

Environmental Quality Mission

The Laboratory supports the cleanup of the Department's environmental legacy through the integration of capabilities in analytical chemistry and chemical separations, biochemical engineering, bioremediation, biotechnology, instrumentation and measurement science and technology, and robotics and intelligent machines. Key research and development activities include

- Environmental management science
- Environmental technology development
- Health and environmental risk assessment

***National Security** Mission*

The Laboratory contributes to the Department's strategic goal of supporting nuclear security, promoting international nuclear safety, and reducing the global danger from weapons of mass destruction through activities in:

- Management and disposition of weapons-related nuclear material
- Promoting nonproliferation and international nuclear safety
- Strategic computing for safe stockpile stewardship

Oak Ridge National Laboratory

Significant Accomplishments

Spallation Neutron Source (SNS): Construction of the SNS, a top-priority project for the Department's Office of Science, has begun. The SNS, a collaboration involving five national laboratories, is an accelerator-based neutron scattering facility that will produce neutron beams six to ten times more intense than any existing pulsed source. It will enable researchers to "see" for the first time the details of physical and biological materials, ranging from high-temperature superconductors to proteins. (1998)

Record-Breaking Scientific Computing: The 1998 Gordon Bell Prize for Best Performance of a Supercomputing Application was awarded to the Laboratory (with Lawrence Berkeley National Laboratory, Pittsburgh Supercomputer Center, and the University of Bristol) for record-setting performance in calculations of magnetic structure. Work since the award has led to a new record: 1.02 teraflops (trillions of operations per second). (1998)

High-Resolution Imaging: The Laboratory's MicroCAT system provides detailed images of soft tissue and bones in mice and other laboratory animals, giving researchers a new tool for studying genetic mutations. The MicroCAT rapidly generates three-dimensional images with 10 times the resolution of conventional tomography systems, and it is the first such system to scan live specimens. The MicroCAT, used at ORNL to study fat deposits in a genetically engineered obesity-prone mouse, will be commercially available in 1999. (1998)

Reducing the Nuclear Threat: A monitoring system developed for the Highly Enriched Uranium Transparency Program can monitor the flow of fissile material in process piping without penetrating the piping. The system will be used to monitor "downblending," a process for producing reactor fuel that uses uranium from dismantled nuclear weapons. Two systems have been shipped to Russia. (1998)

Biomolecular Electronics: ORNL researchers have demonstrated the selective orientation of Photosystem I (PSI) reaction centers. Each PSI reaction center is a photodiode and a nanometer-scale solar battery, offering intriguing possibilities in molecular electronics and biotechnology. These results provide a rational strategy for controlled functional orientation of these molecules on a surface, a required first step in the development of true nanofabricated biomolecular devices. (1997)

High-Temperature Superconductors: The Laboratory's RABiTS™ process combines low-cost textured metal substrates and thin-film superconductors to produce superconducting tapes with high critical current density. A tape produced with RABiTS™ had a critical current density of 700,000 amperes per square centimeter at a temperature of 77 kelvin. (Standard household wires typically carry less than 1,000 amperes per square centimeter.) These tapes could lead to more efficient transformers, motors, and generators. (1996)

Neutron Scattering: The Laboratory's pioneering work in neutron scattering, which began on the Graphite Reactor in the 1940s, was recognized in 1994 when the Nobel Prize in physics was awarded to Clifford Shull. Shull and his colleague, the late Ernest Wollan, developed a method for using patterns of scattered neutrons to determine the arrangement of ordinary and magnetic atoms in solid samples. Their efforts and those of Bertram Brockhouse, who shared the prize with Shull, gave rise to the field of neutron science. (1994)

Software Development: Two software packages developed by the Laboratory and its partners—PVM (Parallel Virtual Machine) and HPSS (High Performance Storage System)—have won R&D 100 awards. PVM permits a large, diverse collection of computers to work together as a single powerful computer and is used at hundreds of computing sites throughout the world. HPSS is the industry standard for managing very large data archives. (1993–1998)

Atomic Imaging: Using the *Z*-contrast imaging technique developed at the Laboratory and the world's highest-resolution scanning transmission electron microscope, researchers produced the first direct images of the structure and chemical identity of atoms at critical regions inside solids. The discovery of unexpected structures in semiconductors, ceramics, and superconductors has brought unique insights into the macroscopic properties of these materials, pointing the way to methods for improving a wide range of advanced materials. (1988)

Battery Development: Thin-film batteries developed at the Laboratory can be deposited directly onto integrated circuits (chips) or chip packages of any size or shape, and they can be recharged thousands of times. The small size and high energy density of these batteries are leading to improvements in products such as sensors, implantable defibrillators, and neural stimulators. Three license agreements for the technology have been signed, and manufacturing scale-up is under way. (1987–present)

High-Temperature Materials Development: Work at the Laboratory has led to the development of two classes of structural materials—whisker-toughened ceramics and ductile intermetallic alloys—and to processes and products with significant economic impacts. Whisker-toughened ceramics are sold as cutting tools. Gelcasting, a process for making high-quality ceramic parts in complex shapes, is used in manufacturing turbine rotors, thermal insulation for engine exhaust manifolds, and magnet rings for particle accelerators. The Exo-Melt process saves time and energy in manufacturing nickel aluminides (used for furnace trays, belts, and rollers) and iron aluminides (used for hot-gas filters and heating elements). A ceramic composite filter developed with the 3M Company is lighter, more reliable, and more efficient than conventional filters in fluidized-bed combustion systems and coal gasification plants. (1981–present)

Record of Innovation: The Laboratory has won 96 R&D 100 awards, a total exceeded only by General Electric and NASA. The awards are presented annually by R&D magazine for the year's 100 most significant technological innovations. (1963–present)

Cryobiology: Laboratory researchers pioneered the development of techniques for preserving life in a frozen state. A wide variety of cell types have been preserved. Cryopreservation of early mammalian embryos has had a profound effect on livestock breeding, preservation of endangered species, human fertility problems, and genetic research. Cryopreservation of the embryos of fruit flies, a major experimental organism for genetics and developmental biology, was successfully demonstrated at the Laboratory in 1990, opening the way to less expensive means of preserving genetically important mutations. (1962–present)

Genetics and Genomics: The field of mammalian genetics, studied at the Laboratory since 1948, was advanced by the 1979 identification of ethylnitrosourea (ENU) as a "supermutagen" and the development of effective ENU mutagenesis assays. Today's comprehensive program combines the Laboratory's mutant mouse stocks, expertise in genetics, and strengths in analytical technologies, bioinformatics, and computational biology to support the Human Genome Project. (1948–present)

Isotope Development and Production: The Laboratory has produced isotopes for medicine, research, and industry for more than 50 years. It is the principal supplier of several isotopes used in cancer treatment, nondestructive testing, and explosives detection. The Laboratory also contributes to nuclear medicine by developing methods for producing and processing radioisotopes for research and clinical use. Applications include cardiac imaging, bone pain palliation, and selective tumor destruction. (1946–present)

Oak Ridge National Laboratory

Major Partnerships, Collaborations, and Cooperative Research and Development Agreements

Category/Mission	Partner	Description
ORNL partners with other national laboratories, universities, industry, other government agencies, and international research institutions. Almost 75% of ORNL research articles include coauthors from other institutions. The Laboratory's 15 user facilities offer extensive opportunities for collaboration, and more than 500 user agreements are in place. About 4,000 guests work at ORNL each year; 25% are from industry, and agreements with industry partners dominate new user facility activity. ORNL has university partners in 48 states and annually hosts hundreds of guest researchers from other nations.		
Science & Technology	ANL, BNL, LBNL, LANL	Spallation Neutron Source project
	ANL, LBNL; U. Illinois, NIST	Materials Microcharacterization Laboratory
	PPPL; universities	National Spherical Torus Experiment; National Compact Stellarator Experiment
	Tennessee universities and research institutions	Tennessee Consortium for Mouse Functional Genomics to accelerate the development of mouse models for human diseases
	U. California–San Diego	Virtual Laboratory for Technology (to meet emerging needs in fusion technology)
	SEMATECH	Improvements in semiconductor manufacturing technology
Science & Technology, Energy Resources	ANL, NREL, PNNL, SNL; universities	Biofuels Feedstock Development Program
	INEEL; SNL	Development of laser-assisted arc welding
	Industry; ANL	Superconductivity Partnership Initiative Power Cable Project
	North Carolina A&T State U.	Collaborative research in high-temperature materials; NSF-sponsored Center for Advanced Materials and Smart Structures (with North Carolina State U.)
Science & Technology, Energy Resources, Environmental Quality	U. Tennessee	Science Alliance; Distinguished Scientist Program; graduate programs; joint institutes; joint research centers
	Federal agencies; GA, NC, TN	Southern Appalachia Man and the Biosphere Cooperative
Science & Technology, Environmental Quality	DOD, DOE, EPA, federal and nonfederal organizations	Strategic Environmental R&D Project
Energy Resources	Industry; federal agencies; universities; national labs	Partnership for a New Generation of Vehicles
	Organisation for Economic Cooperation and Development	Participation in Nuclear Data Bank, support for OECD Nuclear Energy Agency
Energy Resources, Environmental Quality	Nuclear Regulatory Commission	Nuclear safety, safeguards, and environmental protection activities; assistance in licensing and other regulatory actions and decisions
	Latin American universities, U.S. universities; ANL, SNL; industry	Consortio Educativo para la Proteccion Ambiental
National Security	DOE labs and facilities	Interlaboratory Task Force on Unexploded Ordnance, in support of DOD
	Newly Independent States	Initiatives for Proliferation Prevention

Performance Metrics