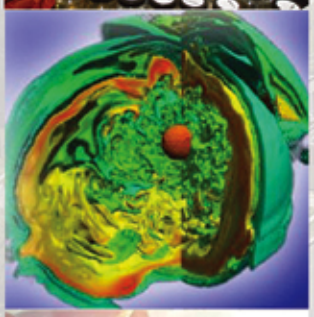
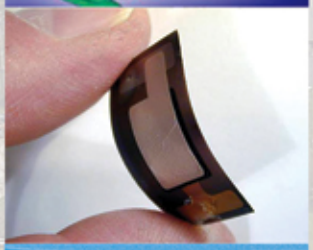
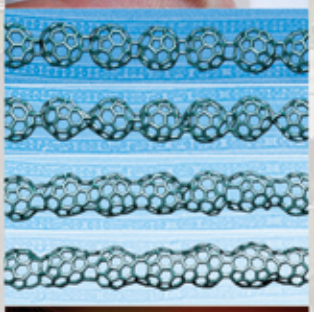
OAK RIDGE NATIONAL LABORATORY

Institutional Plan

FY 2004 – FY 2008







OAK RIDGE NATIONAL LABORATORY

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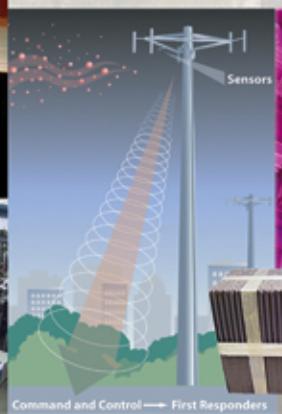

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OAK RIDGE NATIONAL LABORATORY INSTITUTIONAL PLAN

FY 2004–FY 2008

September 2004

Prepared by
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831-6285
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Laboratory Director's Statement

Jeffrey Wadsworth
Director
Oak Ridge National Laboratory

I am both proud and excited to be leading the Oak Ridge National Laboratory (ORNL) at this time of extraordinary opportunity. Remarkable progress is being made across all areas of the aggressive agenda laid out by the UT-Battelle team in 2000: science and technology; operations and environment, safety, and health; and community service.

Since arriving at ORNL in August 2003, I have been tremendously impressed by the world-class scientific research capacity that is being developed to support the needs of the Department of Energy (DOE). It is now possible to look across the ORNL campus and quite literally see the future in the suite of new research facilities that will be completed in the next few years. These facilities will substantially strengthen ORNL's capabilities in three critical areas: nanoscale science and technology, ultrascale computing and simulation, and complex biological systems.

- The Spallation Neutron Source (SNS) is more than 68% complete and on schedule to begin operations in 2006. The SNS and the upgraded High Flux Isotope Reactor will afford unique opportunities for fundamental studies of nanoscale materials. To take advantage of these opportunities, we are building the Center for Nanophase Materials Sciences adjacent to SNS. Complementing these resources are some of the world's highest-resolution electron microscopes, which will soon be housed in a new Advanced Materials Characterization Laboratory.
- With the opening this summer of a new Computational Sciences Building, ORNL is home to the nation's largest computer center for unclassified scientific research. The systems and equipment housed in this facility are essential resources for the solution of complex scientific problems.
- We are securing the capabilities needed to deliver an integrated and predictive understanding of biological systems. Our strengths in structural molecular biology, microbial genomics, genome-scale proteomics and protein complex analysis, computational biology and bioinformatics, and studies of gene and protein function are being focused on the challenges of DOE's Genomes to Life program. The new Laboratory for Comparative and Functional Genomics will offer support to this area.

Among the most intriguing possibilities afforded by our new capabilities is the chance to explore the nexus of these three areas. As Jack Marburger, the President's science advisor, has observed, we are beginning to be able to conceive, design, and build from the atomic level. At ORNL, we are assembling a phenomenal set of tools for observing, fabricating, manipulating, and modeling materials at the atomic scale. Our ability to integrate these distinctive resources and apply them to emerging challenges, in partnership with researchers from other laboratories, universities, and industry, can be expected to lead to revolutionary advances in science and technology.

These advances will, in turn, produce solutions to a broad range of problems. The ability to translate science into practical solutions for urgent problems is a hallmark of the national

laboratories. At ORNL, we are intensifying our focus on two areas of particular importance to DOE and to the nation: energy security and national security.

Our efforts to develop systems and technologies that foster a diverse supply of affordable and environmentally sound energy will emphasize next-generation nuclear power, fusion energy, and hydrogen. Complementing this emphasis will be work to improve the reliability of the nation's electricity transmission and distribution, expand the use of distributed energy resources, and advance energy efficiency in buildings and transportation systems.

In applying advanced science and technology to the nation's defense, we not only support DOE's goals in nuclear nonproliferation but also address the problems of prevention, deterrence, detection, mitigation, and identification of the use of weapons of mass destruction. We will continue to leverage our diverse resources to develop tools for combating terrorism and enhancing national security.

These are formidable challenges, but ORNL is exceptionally well positioned to deal with them. Thanks to a strong partnership between UT-Battelle, DOE, the state of Tennessee, and the private sector, a 21st century laboratory is emerging from construction sites across the ORNL campus. We are eagerly looking forward to the research opportunities that come with these facilities, and we are committed to making the most of our physical and intellectual resources to deliver excellence in science and technology.

At the same time, we remain deeply committed to responsible stewardship of these resources. Our facilities modernization effort extends beyond the construction of new buildings to ensure that existing facilities support our mission assignments. Aggressive action has been taken to improve the discipline and integration of operations at ORNL, with heartening results in improved safety performance, reduced exposures of personnel to hazards, and disposal of immense quantities of legacy materials. We have implemented systems for proactive planning, effective allocation of resources, and rigorous assessments of performance to support the execution of the Laboratory Agenda and enable us to deliver on our mission assignments.

Since coming to ORNL in August, I have observed a remarkable level of enthusiasm and commitment throughout the organization. There is a great sense of excitement about the opportunities that lie ahead of us. Thanks to UT-Battelle's commitment to good corporate citizenship, this sense of excitement is mirrored in the surrounding community. An extensive network of partnerships underpins our efforts in science education, community involvement, and economic development.

The Laboratory celebrated its 60th anniversary in 2003, looking back to its crucial role in the Manhattan Project and its evolution into a unique resource for contributing to our nation's security and economic strength. As we prepare to deliver the science and technology that will change the world of the 21st century, I am very much aware that we are building on a record of excellence established by those who came before us. The standard that they set for ORNL will be our guide as we advance the frontiers of knowledge, develop new technologies, and provide the world-class facilities that will support and sustain the nation's research enterprise.

Mission and Roles

The Oak Ridge National Laboratory (ORNL) is an Office of Science multiprogram national laboratory providing broad support to the Department's overarching national security mission, as articulated in the Department of Energy draft strategic plan released August 6, 2003. ORNL combines distinctive capabilities in materials science and engineering, neutron science, computational science, energy technology, mammalian genetics, environmental science, and nuclear science and technology to deliver new knowledge and technologies to achieve DOE objectives and meet national needs.

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

Mission Roles

Science

The draft DOE strategic plan states as General Goal 5 that DOE will "provide world-class scientific research capacity needed to ensure the success of Department missions . . . , to advance the frontiers of knowledge . . . , and to provide world-class research facilities . . . ." ORNL has two broad roles in support of this goal: operation of major research facilities on behalf of the scientific community and conduct of basic research, primarily in the materials and chemical sciences, the life and environmental sciences, fusion energy, computational science, and nuclear physics.

ORNL's user facility role is increasing in both scientific impact and size and scope. New capabilities are becoming available to the scientific community through construction of the Spallation Neutron Source and the Center for Nanophase Materials Science and the growth of the Center for Computational Science into one of the nation's premier civilian scientific computing facilities. These efforts, coupled with the re-invigoration of the High Flux Isotope Reactor as a major neutron scattering facility in its own right, significant upgrades to the Holifield Radioactive Ion Beam Facility, completion of a new Functional Genomics Facility, and several other enhancements to ORNL instrumentation and facilities, are providing a new generation of extraordinary tools for our nation's scientists. Strategies to ensure the timely completion, effective operation, and scientific productivity of major research facilities are described in the body of this document.

ORNL carries on a broad portfolio of basic research in support of DOE's Office of Science, the largest single sponsor of research at ORNL. Major thrust areas include materials science, with emphasis on nanoscale phenomena and neutron scattering, computational science, and the study of complex biological systems. Primary clients within the Office of Science include DOE's Offices of Basic Energy Sciences, Biological and Environmental Research, Advanced Scientific Computing Research, Fusion Energy Sciences, and Nuclear Physics. The Laboratory also receives support from other federal sponsors of basic research.

Energy Resources

The Department's draft strategic plan establishes as General Goal 4 that DOE will "enhance energy security by developing technologies that foster a diverse supply of affordable and environmentally sound energy, improving energy efficiency, providing for reliable delivery of energy, exploring advanced (energy) technologies . . . , and guarding against energy emergencies." ORNL conducts the nation's largest and most broadly based energy research and development program in support this goal. Primary supporters of ORNL's programs include DOE's Offices of Energy Efficiency and Renewable Energy, Fossil Energy, and Nuclear Energy, Science and Technology; the new Office of Electric Transmission and Distribution; the Department of Transportation; and the Nuclear Regulatory Commission. Energy-related work is also sponsored by the Department of Defense and the Environmental Protection Agency through ORNL's Work for Others program.

ORNL's energy programs are evolving in line with changes in the nation's needs and advances in science and technology, as reflected in Administration research initiatives and DOE programmatic direction. Accordingly we are seeing new emphasis and increased effort in science and technology related to the potential use of hydrogen as a major energy source throughout the economy, on technologies for enhancing the stability and reliability of our electrical grid, and on science and technology for advanced fission and fusion power generation. We also conduct substantial programs in energy-efficient technologies for buildings, industrial, transportation, and utility end use; bioenergy, with a focus on sustainable biomass feedstock and conversion technologies; distributed energy resources, emphasizing integrated systems and utility reliability; carbon sequestration; and fossil energy, emphasizing applied materials, fuel cells, and efficient turbine systems.

National Nuclear Security

ORNL contributes to DOE's national security mission primarily through support to DOE's General Goal 2: "Provide technical leadership to limit or prevent the spread of . . . weapons of mass destruction; advance the technologies to detect the proliferation of weapons of mass destruction . . ., and eliminate or secure inventories of surplus materials and infrastructure useable for weapons of mass destruction." ORNL supports the effort to reduce the global nuclear danger through national nuclear security, nuclear safety, and nonproliferation efforts in three areas:

- management and disposition of weapons-related nuclear material;
- nonproliferation and international nuclear safety, with an emphasis on reducing the threat from biological, chemical, and nuclear agents; and
- modeling and simulation of the effects of biological, chemical, and nuclear releases using high-performance computing.

Primary support for these efforts is provided by the National Nuclear Security Administration (NNSA) Office of the Deputy Administrator for Defense Nuclear Nonproliferation. The DOE Office of Fissile Materials Disposition supports the development of nuclear-based technologies for fissioning surplus plutonium in power reactors and efforts to dispose of surplus ^{233}U.

With the formation of the Department of Homeland Security, ORNL's national security role is evolving. ORNL has been identified as a Department of Homeland Security laboratory, and we anticipate research roles particularly in areas related to detection, inhibition, and response to the

use of nonconventional weapons and radiation dispersal devices in the United States. ORNL also provides an increasingly broad range of research and development support to the DOE Offices of Counterintelligence, Intelligence, and Security and Emergency Operations; the Department of Defense; the Department of Justice; the Federal Emergency Management Agency; the Federal Aviation Administration; and other government agencies with a focus on intelligence collection and analysis, national security, law enforcement, and public safety.

Environmental Management

General Goal 6 in the draft DOE strategic plan states that DOE will "Accelerate cleanup of nuclear weapons manufacturing and testing sites . . . ." ORNL supports the cleanup of DOE's environmental legacy through the integration of capabilities in analytical chemistry, biochemical engineering, bioremediation, biotechnology, chemical separations, earth and ecological sciences, environmental chemistry and engineering, geological sciences, instrumentation and measurement science and technology, and robotics and intelligent machines. Although the volume of ORNL's work has decreased in line with the accelerated cleanup strategy emphasis on near-term cleanup operations, we continue R&D activities in environmental management science, environmental technology development, and life-cycle analysis and health and environmental risk assessment.

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

Other Activities

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

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

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

Major Facilities

An important part of DOE's science mission is conceiving, constructing, and operating large-scale, complex facilities for R&D. ORNL is home to 17 designated national user facilities (more than any other national laboratory) that are available to laboratory, industrial, and academic users. It also operates a number of other facilities that are used in executing DOE missions.

Major Partnerships and Collaborations

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

R&D partnerships and collaborations are described in each initiative and program area presented in this plan. Planned work for other sponsors, which helps ORNL to maintain the R&D expertise available to DOE and broaden the application of the Laboratory's strengths to mission-related needs, is described in the Supplemental Information appended to this report. Technology transfer and economic development activities are described on page 183, and education partnerships are discussed on page 191.

Major facilities at ORNL

Designated user facilities

Bioprocessing Research Facility
Buildings Technology Center
Californium User Facility for Neutron Science
Computational Center for Industrial Innovation
Cooling, Heating, and Power Integration Laboratory
Fuels, Engines, and Emissions Research Center
High Flux Isotope Reactor
High Temperature Materials Laboratory
Holifield Radioactive Ion Beam Facility
Metals Processing Laboratory User Center
Mouse Genetics Research Facility
National Transportation Research Center
Oak Ridge Electron Linear Accelerator
Oak Ridge National Environmental Research Park
Physical Properties Research Facility
Power Electronics and Electric Machinery Research Facility
Shared Research Equipment Collaborative Research Center

Other key facilities

Center for Computational Sciences
Center for Engineering Science Advanced Research
Free Air Carbon Dioxide Enrichment Facility
Irradiated Fuels Examination Laboratory
Multicharged Ion Research Facility
Nanoscale Science and Technology Laboratory
Natural and Accelerated Bioremediation Research Program Field Research Center
Radiochemical Engineering Development Center
Robotics Technology Assessment Facility
Seafloor Process Simulator
Spallation Neutron Source (under construction)
Walker Branch Throughfall Displacement Experiment

Laboratory Strategic Plan

UT-Battelle assumed responsibility for the management and operation of Oak Ridge National Laboratory in the spring of 2000. The UT-Battelle leadership team refined and began executing a new strategic plan that had been initially prepared as part of UT-Battelle's proposal. That plan, founded on a philosophy of simultaneous excellence in science and technology, laboratory operations, and community service, was built around three strategic objectives:

- A broad effort to strengthen ORNL's science and technology base and mission roles, building on and enhancing the Laboratory's long-standing strengths in materials science, computation, and energy research; renewing ORNL's life sciences programs; and expanding ORNL's contributions to DOE's national security mission.
- Revitalization of ORNL's human capital and aging research facilities and infrastructure.
- Expansion of ORNL's role in the community, with particular emphasis on science education and community service.

Strategic Planning at ORNL

Our strategic planning process is the principal tool by which, in partnership with the Department of Energy (DOE) leadership, we integrate short- and long-term requirements and develop a strategy and implementation plan that responds to both. Each year we take a fresh look at our aspirations and goals for ORNL, considering new technical directions, specific challenges, and strategies for achieving them. We perform a situation analysis, reviewing our current situation and external factors that could influence our choices, major trends, and opportunities. We review the Laboratory's principal needs and formulate plans to address them. Our major actions are captured in the ORNL Laboratory Agenda, which provides a structured framework for communicating our major strategic thrusts and the associated actions.

Since that time, and in close partnership with DOE, we have made very substantial progress in all three areas. Although substantial challenges remain, we are confident that we will realize the critical outcomes that we laid out in 2000 by 2006 or 2007. Consequently the emphasis of our strategic planning is shifting from ensuring progress against the very aggressive agenda that we laid out at the beginning of the decade to preparing for what comes next. The questions we are asking include the following:

- What new scientific opportunities are offered by the extraordinary combination of scientific capabilities being created at Oak Ridge National Laboratory?
- What new opportunities do these capabilities offer to help meet the nation's present and emerging energy and national security challenges?
- How will we attract and retain the outstanding researchers and support staff necessary to realize these opportunities?
- What are the most urgent needs to address in a second phase of facilities revitalization and infrastructure renewal?
- How can we best continue our progress in making ORNL a vital contributor to education and community development in our region?

Our strategic plan is evolving to reflect our initial answers to these very challenging questions.

Situation Analysis

Strategic planning for a national laboratory begins with our best understanding of national needs and of the dependence of potential solutions to those needs on science and technology and on an honest assessment of the strengths and capabilities of that laboratory. It is not possible to provide a detailed analysis of these factors in the space available here, but the following paragraphs summarize the major items that we have considered in our planning.

National Needs and the DOE Mission

If ever a year reminded us of the enduring importance of DOE's missions, 2003 was such a year. Developments throughout the year have effectively reenforced the magnitude and impact of our national security and energy challenges and help us understand the requirements that effective solutions must meet.

- From the Middle East to the Korean Peninsula, events around the world continue to demonstrate that preventing the proliferation of weapons of mass destruction and countering terrorism will be enduring challenges. These challenges require both the efficient deployment of our best available technologies and expertise today and the development of more effective and complete solutions for the years to come.
- As this summer's major electrical grid blackout forcefully reminded us, the nation's widespread, and increasing, dependence on interconnected critical infrastructures (banking and finance, energy, telecommunications, transportation, water systems, and essential government services) cry out for more reliable, more secure, and cost-effective technologies. Our systems must become more robust against engineering failures and physical and cyber threats.
- Continuing turmoil in the Middle East, coupled with the dominant role of growing U.S. petroleum imports in meeting our energy needs, reenforces the urgency of a technologically and economically feasible path to greater energy independence. Also of great importance, although less visible in the headlines, is the need to enable economic growth worldwide while mitigating the potentially adverse climate impacts of carbon dioxide emissions. In consequence we are seeing a growing policy commitment to development of a range of energy alternatives, from more reliable and affordable nuclear power to the technologies necessary to employ hydrogen broadly in the U.S. economy. The 2003 U.S. decision to rejoin the international consortium building ITER, a major fusion research facility, highlights this trend.
- There is a growing consensus that increased support for physical sciences research, including those fields largely supported by the Department of Energy Office of Science, and the interface between the physical sciences and the life sciences, engineering, and other fields, is in the national interest. Over the last year, particularly, that view has been broadly expressed and reflected in proposed legislation. However, competing demands for resources and deterioration in the nation's fiscal situation are likely to limit new research funding in the near and intermediate term.

Science and Technology

For several years the science and technology communities have celebrated the spectacular progress in computing and information technology, exploration of biological processes at the molecular level, and advances in our ability to characterize and manipulate matter at the molecular or atomic scale. These advances are being translated with unprecedented speed into new technologies in our

workplaces, homes, and hospitals; enhancements to our transportation, energy, and other critical infrastructures; and new tools for protecting our national security. We believe that these three trends will be the dominant scientific and technological themes for at least the first decades of the twenty-first century. Particularly exciting opportunities to advance scientific frontiers and to translate new knowledge into improvements in the human condition and solutions to national needs likely lie at the intersection of these trends.

- Modeling and simulation continues to become increasingly central to a broad range of scientific and engineering fields, drawing on and driving advances in computational science and computing power. Continuing advances in computing technology and modeling software allow us to model complex natural and engineered systems with increased spatial and temporal resolution, with more accurate physics, and across multiple spatial and temporal scales. New communications and networking capabilities allow us to bring together researchers and information from around the globe to solve the most demanding scientific and technical challenges. Spectacular though the advances to date are, we believe that we are barely beginning to see the full potential impacts of modern computing technology on science, engineering, and, indeed, society.
- As our experimental and computational tools continue to advance, our ability to investigate complex biological systems at a fundamental level is growing rapidly. Improved fundamental understanding of biological systems underlies not only improvements in human health and medical care but also our understanding and stewardship of the natural environment, delivery of goods and services through biologically based processing methods, our capacity to meet growing energy needs with reduced environmental impact, and our ability to respond to biological weapons.
- Continued advances in our ability to image and manipulate matter at molecular and atomic scales offer extraordinary scientific opportunities and technological advances. In combination with advances in computing and in our understanding of biological self-assembly processes, emerging abilities to work at the nanoscale promise to make a reality of the long-articulated vision of “materials by design,” with dramatic consequences almost certain across most areas of science and technology.

Developments at ORNL

ORNL is not the same laboratory it was even three or four years ago. We are greatly extending our core materials science capability with new neutron scattering capabilities at the High Flux Isotope Reactor (HFIR), steady progress towards on-time, on-budget completion of the Spallation Neutron Source (SNS), initiation of construction on the Center for Nanophase Materials Science (CNMS), and advances in high-resolution electron microscopy. Remarkable new computational capabilities are coming into existence with the completion of our new Computational Sciences Building, installation of the initial cabinets of the Cray X1 architecture, and advances in our climate, fusion, and materials science simulation capabilities. Substantial participation in three major “Genomes to Life” awards, completion of a new vivarium to support our mouse genetics work, and expansion of our relationship with the National Institutes of Health are bringing new energy to our life sciences research. Our national security work has grown in both volume and impact as ORNL capabilities are applied to both long-standing and emerging challenges, and we are adding some exciting new directions and capabilities to the nation’s largest and broadest energy research effort. Expanded or new partnerships with many of the nation’s and region’s leading research universities have been integral to much of this progress.

The most visible sign of change at Oak Ridge is the extensive construction program that is reshaping and renewing the Laboratory. Less visible, but every bit as important to our future, are our efforts to improve safety performance, improve operational efficiency and cost-effectiveness, address an acute legacy materials issue, and bring staff salaries up to market levels. In every one of these areas we have made meaningful improvements. We are also proud of the record of community engagement that ORNL staff are setting through the "Team UT-Battelle" program to support volunteerism, through their pacesetting contributions to United Way, and through individual efforts too diverse to characterize.

In sum, these developments are setting the stage for extraordinary contributions today and in the years to come, fully consonant with the remarkable history of this Laboratory. This progress not withstanding, however, in partnership with DOE we must continue to address serious challenges if we are to ensure ORNL's future.

- We must plan and conduct a second phase of facilities modernization effort. Combined investments by DOE, the private sector (through the UT-Battelle Development Corporation), and the state of Tennessee are addressing ORNL's long-standing critical need for facilities modernization and infrastructure revitalization. These investments are providing facilities suitable for leading-edge research and allowing us to retire roughly 1.8 million square feet of space in outmoded and largely decrepit buildings, reduce the cost of facilities operations, and improve research productivity. Even after completion of the current projects, however, an unacceptably large fraction of ORNL's physical plant will consist of outdated, costly, and dilapidated buildings and highly inefficient, and often badly decayed, infrastructure incapable of supporting modern scientific work.
- The cost of doing business remains a major issue for ORNL. The UT-Battelle leadership team is committed to and has delivered substantial reductions in overhead costs. The savings have, however, been redeployed to address urgent needs, including facilities and infrastructure revitalization, bringing staff compensation up to market level, and meeting the costs for cleanup of large volumes of unneeded material, new legacy workers' compensation program, and other legacy issues. We also face productivity issues in some key support areas. In consequence, overhead rates remain higher than is desirable.
- Nuclear science and technology remains one of the signature capabilities of ORNL. However, our nuclear facilities and operational practices require attention. During FY 2003 we carried out a thorough review and revamping of our operation of the High Flux Isotope Reactor in response to serious operational issues. Safe, compliant, and cost-effective operation of our non-reactor nuclear facilities also requires continuing attention. Consolidating and modernizing our nuclear complex to meet future mission needs and improve efficiency is an essential, but costly, challenge.
- A substantial fraction of ORNL's research staff will become eligible for retirement over the next 5 to 10 years. Substantial effort will be required to attract and retain the outstanding people necessary to carry on ORNL's tradition of excellence.

Targets and Directions—Laboratory Agenda

The Laboratory Agenda is focused on the most significant activities that UT-Battelle must accomplish to deliver on its vision of simultaneous excellence in science and technology, Laboratory operations and ES&H, and community service. The Laboratory Agenda as presented here includes statements of the primary results that will be delivered to DOE over the next few years. The actions by which these outcomes will be delivered are presented in the following sections of this Institutional Plan.

Strategic Objective 1: Excellence in Science and Technology

We will prepare the Laboratory to address future national needs for science and technology through major initiatives that sustain and extend its distinctive capabilities. ORNL will also continue to deliver scientific advances and technological innovations in support of DOE's missions and to make its knowledge and expertise available to non-DOE customers.

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

The Laboratory Agenda

The ORNL Laboratory Agenda summarizes ORNL's strategic intent and the critical outcomes that the Laboratory will deliver over the next several years. The Agenda is updated at planning workshops in the spring and fall, and progress against it is reviewed roughly every quarter. It serves as a base document for internal communication of Laboratory strategy and development of the ORNL Institutional Plan and annual Performance Evaluation Plan, as well as for ORNL's self-assessment process, for our annual planning, and for performance management. A more extended version of the Laboratory Agenda is maintained on the ORNL Web site and includes the primary actions by which the critical outcomes will be achieved.

We are committed to the following actions:

- Establish the nation's premier nanoscience center and user program
- Develop and maintain leadership research capabilities in key areas of materials science and chemical science
  - Complete the Advanced Materials Characterization Laboratory (AMCL)
  - Initiate development of the next-generation electron microscope
  - Establish a world-leading program in nanocatalysis
- Develop and expand partnerships with universities, industry, and other DOE programs that complement and extend the research agenda

Strategic Objectives	Excellence in Science & Technology	Excellence in Laboratory Operations & ES&H	Excellence in Community Service
Critical Outcomes	Deliver scientific advances and technological innovations that support DOE missions, apply expertise and capabilities to the needs of other customers, and sustain and enhance ORNL's distinctive capabilities	Sustain and improve ORNL's ability to serve the needs of DOE and the nation through responsible stewardship	Be viewed by our neighbors as a highly valued partner in the region
Laboratory Initiatives	Advanced Materials Complex Biological Systems Fission to Fusion Future R&D Directions Grid Modernization National Security Neutron Sciences S&T for a Hydrogen Economy Terascale Computing and Simulation Science University Partnerships	Enhance Operational Discipline Facilities Modernization Maximizing Research Productivity Consolidation of Nuclear Capabilities Resolve Legacy Issues Workforce Planning and Development	Economic Development Community Involvement Science and Math Education

Major elements of ORNL's Laboratory Agenda.

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

We are committed to the following actions:

- Establish world-renowned hub for systems biology and biotechnology leveraging specific strengths at ORNL in microbial genomics, plant genomics, mouse genetics and genomics, biophysics and biochemistry, mass spectrometry, neutron scattering, and computational biology
- Bid and win DOE "Molecular Machines" facility and utilize capabilities in systems biology to support the DOE genomics program and related DOE programs with distinction
- Establish real linkage between fundamental systems biology and biotechnology relevant to DOE missions and to other potential funding agencies, and develop new funding
- Use systems biology and biotechnology focus to secure support from the National Institutes of Health and the Department of Homeland Security

3. Fission to Fusion. *Establish ORNL as the main provider of new technologies to support the expanded use of nuclear and fusion technologies to supply the power needs of the world and lead in the development of one or more experimental facilities.*

We are committed to the following actions:

- Provide the nuclear energy community with technologies that will enable cheaper, safer, enhanced proliferation-resistant, and environmentally acceptable use of nuclear energy
- Provide the fusion energy community with scientific and technological advances that will enable the commercialization of fusion energy
- Build and operate experimental facilities at ORNL in support of these and other missions, building a user support base that is unparalleled and enabling outstanding science and technology while maximizing the efficient use of the facilities

4. Future R&D Directions. *We will identify and lay the groundwork for future, long-term R&D directions where ORNL has the opportunity to make extraordinary scientific and program contributions and to build next-generation user facilities, thereby ensuring the Laboratory maintains its status as one of the world's preeminent research laboratories.*

We are committed to the following actions:

- Identify major R&D opportunities across the Laboratory's missions over the next decade and beyond that are well matched to ORNL strengths and build the capabilities necessary to pursue those opportunities
- Identify next-generation user facilities and substantial enhancements to existing facilities that are required to realize the science and technology opportunities that we identify and develop long-range plans for creating those facilities at ORNL

5. Grid Modernization. *ORNL will become the lead lab in support of DOE's Office of Electric Transmission and Distribution (OETD) with the goal of helping to ensure a reliable and secure grid that fully integrates central generations with distributed resources, manages power flows, and meets the nation's need for increasing power quality.*

We are committed to the following actions:

- Develop new materials that revolutionize the performance, reliability, and maintainability of the power grid
- Improve bulk energy storage devices
- Develop fast-responding distributed-generation and price-responsive load shedding techniques
- Develop modeling tools for planning and real-time grid operation

6. National Security. *ORNL will become the premier Office of Science laboratory for providing technology and expertise in support of national defense, homeland security, and related areas.*

We are committed to the following actions:

- Grow sustainable programs in national security technologies to solve compelling national needs and expand scientific frontiers
- Become the preferred national resource for CBRNE research, development, testing, and evaluation for interdiction, detection and response systems
- Construct a state-of-the-art S&T facility in which classified R&D, workshops, and training can be accomplished on the ORNL campus

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

We are committed to the following actions:

- Deliver the Spallation Neutron Source (SNS) on schedule and within budget
- Establish a world-class neutron scattering capability and user program at the High Flux Isotope Reactor (HFIR)
- Develop and maintain leadership research capabilities in key areas of neutron science and nuclear physics
  - 5 out of 16 beam lines at SNS
  - Facility upgrades at the Holifield Radioactive Ion Beam Facility (HRIBF)
- Develop and expand partnerships with universities, industry, and other DOE programs that complement and extend the research agenda

8. Science and Technology for a Hydrogen Economy. *Establish ORNL as a recognized national leader in the development of technologies for hydrogen generation and delivery, hydrogen storage, and in hydrogen-fueled, engine efficiency R&D.*

We are committed to the following actions:

- Establish a leadership role in DOE's hydrogen, fuel cell, and infrastructure programs
- Clearly place the inorganic membranes as the best choice for hydrogen purification
- Establish ORNL as the leader in characterization of storage materials

9. Terascale Computing and Simulation Science. *ORNL will become a world leader in harnessing unprecedented computing power as tools of scientific discovery to deliver new insights and achieve breakthroughs with broad impact in U.S. scientific leadership.*

We are committed to the following actions:

- Lead DOE and the nation in revitalizing U.S. leadership in high-end computing and computational sciences
- Increase Laboratory expertise in modeling, simulation, numerical methods, and future architectures
- Enhance the accessibility of high-performance computing power, both within ORNL and for external partners
- Apply advanced information technology to achieve energy infrastructure assurance and enhanced national security
- Enhance university partnership and research collaborations through the Joint Institute for Computational Sciences

10. University Partnerships. *We will strengthen our role in the nation's research enterprise, increase the quality and impact of our user facilities and science and technology programs, and enhance our contributions to science education by building broad partnerships with the nation's research universities.*

We are committed to the following actions:

- Develop the partner-university model to strengthen Laboratory S&T programs, create major research initiatives, and attract outstanding researchers
- With the University of Tennessee, implement the Joint Institutes for Neutron Sciences, Computational Sciences, and Biological Sciences to stimulate new research collaborations
- Support the Office of Science in strengthening connections with the nation's research universities
- Develop and expand research and educational relationships with historically black colleges and universities (HBCU) and other minority educational institutions
- Create the Oak Ridge Center for Advanced Studies with Oak Ridge Associated Universities (ORAU), Battelle, and our university partners

Strategic Objective 2: Excellence in Laboratory Operations and Environment, Safety, and Health

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

1. Enhanced Operational Discipline. *ORNL will enhance its overall operational performance by improving the discipline and integration of its operations and realigning its security posture to respond to changing situations.*

We are committed to the following actions:

- Deploy a set of integrated management systems that provide user-friendly support to researchers and managers while appropriately controlling work and managing risk
- Instill a culture of operational discipline and critical self-assessment to drive continuous improvement
- Demonstrate continual improvement in ES&H performance, moving towards best in class
- Safeguard the Laboratory's staff, information, and physical assets by utilizing cost-effective strategies that are consistent with our Open Campus initiative

2. Facilities Modernization. *ORNL will construct new facilities and renovate and replace existing facilities and infrastructure to create a modern research campus that enables the conduct of world-class R&D.*

We are committed to the following actions:

- Carry out a Facilities Revitalization Project to design and construct new facilities and renovate existing facilities and infrastructure in support of ORNL mission objectives
- Consolidate Laboratory operations at ORNL's main site
- Assume full responsibility for wastes generated by ORNL operations

3. Maximizing Research Productivity. *ORNL will constrain growth in the cost of doing business while leveraging our people, processes, and new infrastructure to increase overall productivity.*

We are committed to the following actions:

- Reduce G&A overhead rate from 38.6% to 34% by FY 2008
- Continue to improve operations with demonstrable improvements in staff satisfaction with internal services
- Facilitate business growth with systems that accommodate diverse business arrangements and customers

4. Consolidation of Nuclear Capabilites. *ORNL will consolidate nuclear capabilities into a configuration that can be operated in a sustainable fashion while supporting critical mission needs.*

We are committed to the following actions:

- Consolidate into fewer nuclear facilities and shut down facilities for which safe operations cannot be sustained or where adequate mission support work cannot be obtained
- Upgrade facilities that will serve long-term needs so that they are fully compliant with current-day standards
- Operate our nuclear facilities to the highest standards of safety, operational discipline, and efficiency

5. Resolve Legacy Issues. *ORNL will resolve the legacy issues which are critical to sustaining the operations and infrastructure of the Laboratory.*

We are committed to the following actions:

- Identify and dispose of legacy materials that pose a hazard or impede facility revitalization
- Demolish excess facilities
- Minimize the impact of legacy issues on the cost of operations

6. Workforce Planning and Development. *ORNL will attract and retain a diverse workforce of outstanding research and support professionals.*

We are committed to the following actions:

- Enhancing diversity, broadly construed, at ORNL through effective outreach and by ensuring that ORNL provides a welcoming environment to a diverse workforce
- Workforce planning to identify recruiting and staff development needs
- Enhance the benefits package to better address staff and organizational needs while controlling costs
- Improve the effectiveness of HR service delivery through implementation of the HR strategic plan

Strategic Objective 3: Excellence in Community Service

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

1. Economic Development. *ORNL will impact economic growth and development using ORNL technology, personnel, and facilities.*

We are committed to the following actions:

- Apply Laboratory-based ideas, technologies, and facilities to marketplace opportunities to create economic value for ORNL and the local economy
- Expand the use of business intelligence to link available technologies to marketplace opportunities
- Foster and encourage an entrepreneurial culture and spirit at ORNL
- Support robust economic development activities through partnerships with local and regional organizations

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

We are committed to the following actions:

- Enrich the community through a set of legacy investments
- Expand the public's awareness of DOE and ORNL research programs

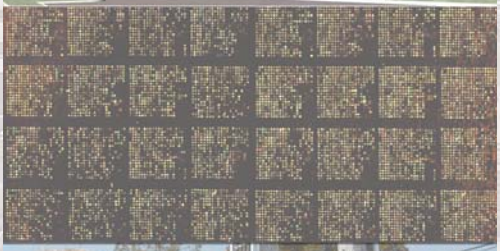
3. Science and Mathematics Education. *We will invest in efforts to improve science and mathematics education in Tennessee.*

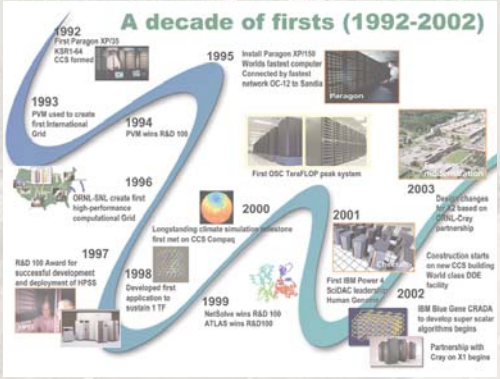
We are committed to the following actions:

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

Oak Ridge National Laboratory

Initiatives





Advanced Materials

Complex Biological Systems

Grid Modernization

Science and Technology for a Hydrogen Economy

Fission to Fusion

Neutron Sciences

Terascale Computing and Simulation Science

Summary

Research initiatives are a primary tool by which Oak Ridge National Laboratory builds research capabilities in particularly promising areas of science and to meet anticipated national needs. These initiatives, typically lasting a minimum of three years, represent substantial organizational commitments that are reflected in our strategic plan and Laboratory Agenda, recruiting priorities, focus areas for our Laboratory Directed Research and Development program, and continuing senior management attention. Each year Laboratory management carefully reviews both existing research initiatives and proposed new areas for progress, scientific and technological promise, match to ORNL's strengths and mission roles, and relevance to DOE missions and evolving national needs.

The portfolio of initiatives presented in this Institutional Plan continues our emphases in materials science at the nanoscale, neutron science, computational science, and the investigation of complex biological systems, all of which are adding important new research capabilities to the Laboratory. Our plans in these initiative areas have been updated to reflect progress, new scientific opportunities, and DOE guidance.

There has been substantial change from what we presented in the FY 2003 Institutional Plan in the energy and national security areas as follows:

- Our long-standing and broadly framed initiative aimed at advanced, environmentally friendly energy technologies ("Energy and Environmental Systems of the Future") has been replaced by three sharply focused initiatives aimed at science and technology for a hydrogen economy, advanced grid technologies, and technologies relevant to new-generation fission and potential fusion power reactors.

- Rapid changes in our national security environment, the governmental reorganization resulting in the creation of the Department of Homeland Security, and rapid growth in ORNL's national security programs are causing us to think carefully about ORNL's future roles and the technical capabilities necessary to support them. In particular we are taking a fresh look at the relationship between ORNL's science and technology base and our likely future national security roles. Although we are continuing to conduct Laboratory Directed Research and Development projects and actively recruit in areas that support our national security programs, we have not included an initiative proposal in this year's plan. Rather, the full discussion of science and technology for our national security programs is contained in the relevant program sections of this document. Based on our ongoing planning, we will likely propose one or two specific science and technology initiatives in key national security areas in the FY 2005 Institutional Plan.

For each proposed initiative we address our strategic intent; prospective impact on DOE missions and national needs; a brief situation assessment; our objectives and the strategies for achieving those objectives; a summary of accomplishments to date; and the key research partnerships on which our progress depends.

Advanced Materials

Strategic Intent and Expected Outcomes

ORNL will position itself as a leader in nanoscale science, engineering, and technology.

Expected outcomes are as follows:

- Establish the Center for Nanophase Materials Sciences as a collaborative research center with five scientific thrusts: soft and hybrid materials; complex hard materials; nanofabrication; theory, modeling, and simulation; and nanoscale imaging and characterization.
- Develop state-of-the-art tools for materials synthesis, characterization, and theory / modeling studies in support of a new generation of advanced materials.
- Extend the Laboratory's synthesis and characterization capabilities in soft materials and materials integration to enable research that will lead to revolutionary new technologies, such as improved catalysts, molecular and biomedical devices, and molecular electronics.
- Secure the next-generation Advanced Materials Characterization Laboratory (AMCL) and associated instrumentation to provide a new generation of advanced capabilities in atomic-scale imaging and spectroscopy.

Significance of Outcomes

As we enter the new millennium, the international science agenda is focused on nanoscale science, engineering, and technology (NSET). Excitement and anticipation surround research that will extend our ability to understand, design, and control materials at the nanoscale.

In a recent report issued by the Office of Basic Energy Sciences (BES), *Basic Research Needs to Assure a Secure Energy Future*, nanoscale science, engineering, and technology were identified as crosscutting areas in which research may provide solutions and insights into long-standing technical problems and scientific questions.

Nanoscale science is integral to many ORNL materials research programs, with efforts crossing the traditional boundaries of materials sciences, condensed matter physics, chemistry, biology, computational science, and engineering. By expanding its capabilities and programs in NSET, ORNL will sustain its position as a world-class advanced materials R&D laboratory. The Center for Nanophase Materials Sciences (CNMS) will provide new and unique capabilities to advance fundamental understanding and control of materials at the nanoscale. It will integrate nanoscale research with neutron science, synthesis science, and theory / modeling / simulation, bringing together four areas in which the United States has clear national research needs. Soft materials research, which has gained increasing interest from the scientific community, is also a part of the NSET program at ORNL. Soft materials, alone or in hybrid systems, have the potential of revolutionizing such areas as sensor technology, health care, functional materials research, and other applications.

As a leader in the development of techniques and instrumentation for analysis of materials at the atomic level, appropriate housing for the Laboratory's advanced analytical instrumentation is a high priority. This equipment is now scattered across the ORNL campus in buildings that do not

meet requirements for optimum operation. The AMCL will provide the high-quality environment required to optimize the performance of sophisticated characterization equipment.

Background

Artist's conception of the Center for Nanophase Materials Sciences.

Nanoscience encompasses the discovery, understanding, and characterization of novel properties, phenomena, and processes that occur in materials smaller than approximately 100 nanometers. A central challenge in nanoscience is the controlled synthesis of such materials. We need to understand and control self-assembly and other growth mechanisms. To predictably yield the desired structures, the specialized state-of-the-art facilities and expertise at ORNL, with its tradition of forming research teams that cross traditional disciplines, will play an indispensable role in this research endeavor. Neutron scattering will play a central role in determining the structure of nanomaterials, in developing and understanding synthesis and self-assembly processes, and for investigating the cooperative phenomena that emerge on the nanoscale. The intense neutron beams available at the High Flux Isotope Reactor (HFIR) and the Spallation Neutron Source (SNS) will make fundamental study of broad classes of related nanoscale phenomena assessable for the first time. Another essential tool for studying nanomaterials is electron microscopy with near-atomic resolution. ORNL's aberration-corrected electron microscopes (ACEMs) will provide unprecedented new capabilities for understanding the structure and properties of nanoscale materials.

Advances in nanotechnology and molecular self-assembly require highly accurate and reliable calculations of the properties of nanoscale systems. Only by applying a combination of theory, modeling, and simulation (TMS) methods, validated by experiment, can one accurately and with confidence design and model complete nanophase systems. By the end of FY 2004, the ORNL Center for Computational Sciences expects to have unique capabilities that will enable, for the first time, ab initio calculations for systems with 10^5 to 10^6 atoms. This translates to ab initio nanoscience at length scales up to 30 nm, approaching the full range of nanoscale phenomena. This exciting prospect will provide the ability to obtain accurate predictions of properties of realistic hard and soft nanophase materials and to investigate entirely new classes of materials, such as those being contemplated in the field of biomimetics.

Objectives and Strategies

Objective 1: *Establish a highly collaborative and multidisciplinary Center for Nanophase Materials Sciences (CNMS) on time and within budget.*

Strategy

- Complete the facility by April 2005 (CD-4a milestone).
- With ongoing input from the user community, procure equipment for installation and operation by September 2006 (CD-4b milestone).

Objective 2: *Broaden ORNL's nanoscale and nanotechnology research programs.*

Strategy

- Advance catalysis science and technology by expanding our understanding of the chemistry of catalytic phenomena and by using this understanding to create new catalysts and position ORNL for leadership in this area.
- Establish strong ORNL research programs in the emerging field that bridges nanotechnology and molecular biotechnology.

Key Accomplishments

- Establish the Center for Nanophase Materials Sciences—in FY 2002, CD-1 and CD-2 approvals were obtained. CD-3 approval was received February 3, 2003. In FY 2003, initiated the user program, including the addition of key user support staff, using existing equipment and expertise.
- Advanced Materials Characterization Laboratory (AMCL)—Building design passed internal 90% design review and external review, and building construction to commence this summer with project completion date of March 2004.
- In 2003, organized DOE Nanoscale Science Research Centers Workshop for the Office of Basic Energy Sciences.
- In 2003, aberration-corrected 300-kV STEM achieved world's best resolution (0.7–0.8 Å).
- ORNL presented a successful multi-lab TEAM (Transmission Electron Aberration-Corrected Microscope) proposal for next-generation electron microscopy.

Objective 3: *Develop the tools for ORNL's nanoscale and nanotechnology research.*

Strategy

- Develop the capabilities for controlled synthesis of nanomaterials and nanostructures resulting in functionality for nanosystems.
- Secure the next-generation Advanced Materials Characterization Laboratory (AMCL) and associated instrumentation, including the world's highest-resolution microscopes.
- Participate in the Transmission Electron Aberration-Corrected Microscope (TEAM) collaboration.

Objective 4: *Establish the Nanomaterials Theory Institute.*

Strategy

- Use ORNL's teraflop-speed supercomputers to investigate the grand challenges of computational nanoscience.
- Initiate the Nanomaterials Theory Institute's workshops.

Objective 5: *Successfully initiate the CNMS user program, building on our FY 2003 start.*

Strategy

- Establish a user outreach program and streamline the process for bringing in guests.
- Provide one-step access to the CNMS and other user facilities.

Key Partnerships

Office of Basic Energy Sciences—Argonne, Brookhaven, Lawrence Berkeley, Los Alamos, Sandia, and Oak Ridge are working together through workshops, lessons learned, etc., to establish the nanoscale science research centers.

Office Basic Energy Sciences—TEAM collaboration involving Argonne, Brookhaven, Lawrence Berkeley, Oak Ridge, and the University of Illinois at Urbana-Champaign.

Budget Information

	Fiscal Year Projections (in millions of dollars)				
	2004	2005	2006	2007	2008
Center for Nanophase Materials Science					
Operating	0.25	9.1	18.075	18.0	18.0
Capital	20.0	17.5	0.0	0.0	0.0
Total	20.25	26.6	18.075	18.0	18.0
TEAM					
Operating	0.20	0.1	0.0	0.0	0.0
Capital	0.65	1.65	0.8	0.3	0.0
Total	0.85	1.75	0.8	0.3	0.0
Total	21.1	28.35	18.875	18.3	18.0

Complex Biological Systems

Strategic Intent and Expected Outcomes

ORNL will be a leading center for understanding complex biological systems, from the molecular level to the level of the organism, and the interactions of organisms with their environment. We will apply our capabilities and knowledge to meet DOE's needs in systems biology, climate change, carbon management, renewable energy, and environmental quality. We will fully support the Office of Biological and Environmental Research (OBER) Genomes to Life (GTL) program, one purpose of which is to provide new tools and resources for systems biology that enable new approaches to discovery.

Our intent will be realized by the following:

- Providing science and technology for understanding microbes and model organisms at the levels of the proteome, metabolic pathways and regulatory networks, interactions of protein complexes, and functions of whole organisms and communities;
- Creating next-generation high-throughput research facilities and resources, with a specific focus on characterization and imaging of protein complexes;
- Producing large-scale data, computational analysis tools and infrastructure, and systems models and simulations of molecular, cell, organism, and ecosystem function.

Significance of Outcomes

Achieving these outcomes will yield critical new knowledge, tools, and large-scale resources needed by the scientific community to address the ultimate goal of modern biology: obtaining a fundamental, comprehensive, and systematic understanding of life at the molecular level. One of these resources will be an integrated, large-scale user facility for characterization and imaging of molecular machines (the multiprotein complexes that carry out the functions of living systems)—one of several designated for the GTL program to provide the broad scientific community with an unprecedented set of capabilities for systems biology.

Our other focus is to link subcellular metabolic processes with the functional performance of communities or whole ecosystems in complex natural environments. This approach will generate novel, integrated experimental and computational methods for analyzing genomes at the level of the biological community and new tools for detecting and simulating the behavior of whole ecosystems.

Achieving our goals will unlock the capability to utilize and control uniquely useful chemical processes in microbes and plants and apply them to DOE (and other) mission needs. One of our ultimate goals is biotechnology solutions to national challenges in clean energy, climate change mitigation, and environmental cleanup. Progress will also benefit the human health–related missions of the DOE, the National Institutes of Health, and Department of Homeland Security, as well as environmental quality missions of the Department of Defense and the Environmental Protection Agency.

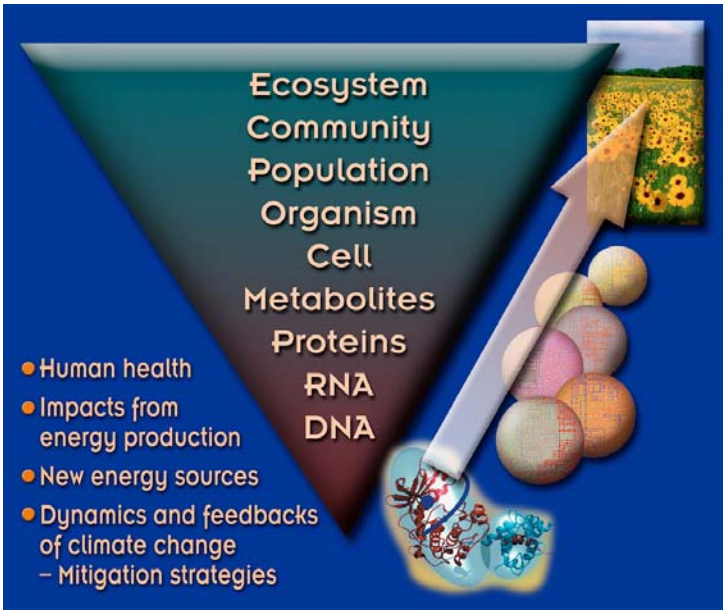
Background

Genome-enabled biology is allowing scientists to address challenges that only could be dreamed about a decade ago. Examples include (1) producing, characterizing, and understanding the function, dynamics, and environmental plasticity of whole proteomes and protein complexes from a wide range of environmental microbes; (2) deciphering genomic information and gene expression patterns from microbes, microbial consortia, and plants to begin to address complex interactions at the community level; and (3) developing a conceptual and experimental framework for exploring and modeling ecological dynamics from the molecular to the ecosystem scale. Tackling these challenges successfully could lead to applications as diverse as efficient bioenergy production schemes to new quantitative tools for predicting and understanding the effects of climate change on critical ecosystems or entire geographic regions.

All information related to the biochemistry, survival, and adaptability of ecosystems is encoded within the metagenome, the complete genetic complement of an entire community or ecosystem. We need new experimental and computational methods for studying gene distribution and expression that are meaningful at these higher levels. New genomic methodology, combined with advances in computational science and the evolving theory of complex adaptive systems, provides the foundation for developing meaningful mechanistic models, from molecular through organism, community, and ecosystem scales.

We will address these challenges by developing advanced analytical and imaging technologies, new biological techniques and understanding, and large-scale research user facilities. We will also develop the computational tools needed to manage the large streams of data from systems biology projects and large-scale facilities and to realistically model complex biological systems.

This initiative draws on our established programs, including GTL, comparative and functional genomics, computational biology, bioinformatics, and analytical and bioimaging technology development. It focuses ORNL's distinctive expertise and facilities in microbial and plant genetics, gene expression, biochemistry, structural biology, environmental microbiology, analytical technologies (including mass spectrometry, imaging, and microfluidics), computational science and applied mathematics, climate change research, physical sciences (including neutron scattering), and engineering on the challenges of observing and understanding the functioning of complex biological systems.



Revolution in genomics and genomic technologies is expected to lead to fundamental understanding of biological processes required to quantitatively describe functions, interactions, and dynamics at scales from the molecular up to that of organisms, communities, and ecosystems.

We will broaden our capabilities via successful partnerships with other

laboratories, universities, and the private sector to foster achievement of our objectives.

Key Accomplishments

- First large-scale comprehensive characterization (868 proteins) of the proteome from a native growth condition of the bacterium *Shewanella oneidensis* obtained by integrating "top-down" and "bottom-up" mass spectrometric approaches—2002.
- New 35-m medium resolution small-angle neutron scattering (SANS) instrument at the High Flux Isotope Reactor, now under construction—2003.
- Microarray-based functional analysis of *Deinococcus radiodurans* identified a new ligase, energy pathway switching, and highly coordinated regulatory response to radiation—2003. This result is important for bioremediation in high-radiation fields and also our understanding of radiation effects on humans.
- Completed whole genome microarrays for *Shewanella oneidensis*, *Rhodopseudomonas palustris*, and *Nitrosomonas europaea*—2003. The Shewanella whole genome arrays serve as the central resource for Shewanella Federation studies.

Objectives and Strategies

Objective 1: *Establish leading capability for GTL research, particularly in the area of molecular machines and protein interactions.*

Strategy

- Develop and test foundational technologies in the current GTL pilot projects as proof of principle for facility-scale data production.
- Create a consortium for a large-scale GTL facility for characterizing and imaging molecular machines.

Objective 2: *Explore fundamental and theoretical science at the interface of biology, chemistry, physics, nanoscience, and nanotechnology and integrate advancements into Complex Biological Systems activities.*

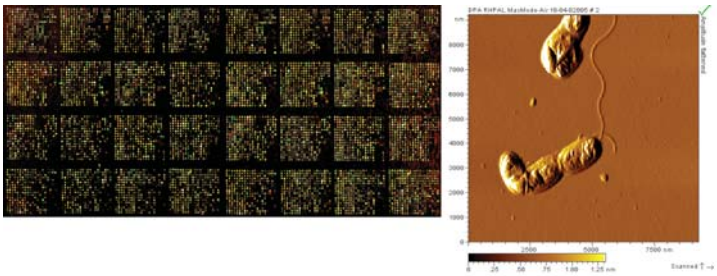
Strategy

- Integrate advanced analytical and imaging technologies, automation, and computational tools and infrastructure into systems biology projects, GTL pilot efforts, and GTL facility planning.
- Exploit new nanoscale materials and tools that bridge nanotechnology and molecular biotechnology for applications in Complex Biological Systems (also see Advanced Materials Initiative).

Objective 3: *Establish facilities and the supporting science and technology to enable a fundamental understanding of biological processes that are required to quantitatively describe functions, interactions, and dynamics at scales from the molecular up to the level of organisms, communities, and ecosystems.*

Strategy

- Develop capabilities in microbial metagenome analysis.
- Create tools that allow us to define and advance the scientific field of ecosystem genomics.
- Advance computational ecosystem science by focusing on mechanistic modeling from molecular through organism, community, and ecosystem scales.



Atomic force microscope image of and gene-expression microarray for* Rhodopseudomonas palustris*, one of the subjects of ORNL's GTL pilot project.

Key Partnerships

- GTL Pilot Projects:
  1. GTL Center for Molecular and Cellular Systems [ORNL led, with imaging technology in collaboration with Pacific Northwest National Laboratory (PNNL)]; other partners include Argonne National Laboratory, Sandia National Laboratories, the University of North Carolina, and the University of Utah
  2. Rapid Deduction of Stress Response Pathways in Metal/Radionuclide Reducing Bacteria [Lawrence Berkeley National Laboratory (LBNL) led, with the University of California (Berkeley), the University of Missouri, the University of Washington, Diversa]
  3. Carbon Sequestration in Synechococcus: From Molecular Machines to Hierarchical Modeling [SNL led, with LBNL, Los Alamos National Laboratory (LANL), the University of California (San Diego), the University of Tennessee, the University of Michigan, the University of California (Santa Barbara), the University of Illinois, National Center for Genome Resources (Santa Fe), and The Molecular Science Institute (Berkeley)]
- Shewanella Federation continuing partnership within GTL to characterize and model the biology of the metabolically versatile bacterium *Shewanella oneidensis* MR-1. It involves over 30 scientists from government, private, and academic institutions including ORNL, PNNL, ANL, Michigan State University, University of South Carolina, Baylor College of Medicine, Institute for Systems Biology, Genomatica, and others.

Budget Information

	Fiscal Year Projections (in millions of dollars)				
	2004	2005	2006	2007	2008
Characterization and Imaging of Molecular Machines					
Operating	7.0	9.0	9.0	10.0	10.0
Capital	0	0	10	40	40
Total	7.0	9.0	19.0	50.0	50.0
Molecular Ecology					
Operating	3.0	4.0	8.0	15.0	18.0
Capital	1.0	2.0	2.0	5.0	2.0
Total	4.0	6.0	10.0	20.0	20.0
Joint Institute for Biological Sciences					
Capital	0.4	1.6	6.0	0.0	0.0
Total	0.4	1.6	6.0	0.0	0.0
Total	11.4	16.6	35.0	70.0	70.0

Note: These projections include funding from DOE and from other sponsors, including the University of Tennessee for the Joint Institute for Biological Sciences (capital only). Projections for Characterization and Imaging of Molecular Machines include both operating funds and capital funds for design, R&D, construction, and equipment for a new GTL facility for characterization and imaging of molecular machines, beginning in FY 2006. The estimated total project cost for he facility is ~$270 million; estimated completion date: end of FY 2009.

Grid Modernization

Strategic Intent and Expected Outcomes

ORNL proposes to conduct the basic research and technology development necessary to help create an electric grid that is more robust against accidents, natural disasters, and physical and cyber terrorism; has the flexibility to incorporate both central and distributed generation; has the embedded intelligence to manage power flows under normal and emergency circumstances; and meets the nation's growing needs for increased transmission capacity and power quality, at an affordable cost.

Our work is intended to create the following:

- New materials for components and devices that revolutionize the performance, reliability, and maintainability of the power grid, including high-performance conductor, cable, and transformer materials; advanced dielectric materials; and SiC- and diamond-based power electronics
- New low-cost grid sensor and communication technologies
- Improved "supercapacitors," flywheels, and other forms of bulk energy storage that can also provide voltage support and power factor correction
- Fast-responding, distributed-generation, and responsive-load technologies
- New high-performance modeling and performance measurement tools for planning and real-time grid operation and control that enable planning for and operation under emergency conditions, optimal routine operation in response to real-time load and pricing data, and quick recovery from system failure

Significance of Outcome

DOE's *National Transmission Grid Study* concludes that the U.S. transmission system is in urgent need of modernization. The system has become congested because growth in electricity demand and investment in new-generation facilities have not been matched by investment in new transmission facilities. Because the existing transmission system was not designed to meet the present demand, transmission constraints increase electricity costs to consumers, the risk of blackouts, and vulnerability to natural disasters and terrorist threats.

By developing better transmission and distribution (T&D) technologies and modeling tools, we will help increase energy reliability and efficiency; reduce costs, line losses, and emissions; improve power quality; and help ensure a robust and reliable electric grid for the 21st century. Accomplishing these goals contributes to multiple national energy and environmental priorities. For example, the President's National Energy Policy calls for DOE to address constraints in electric transmission and relieve bottlenecks in the economic flow of electricity among utilities, states, and regions. The *Transmission Grid Solutions Report*, prepared by the Secretary of Energy's Electricity Advisory Board, provides guidance for priority actions to address congestion on "national interest" transmission corridors.

Background

The Energy Information Administration forecasts the generation of electricity to grow by 70% over the next two decades. To handle this increase, new technologies to respond to the following challenges are needed.

- The materials with which the T&D system is constructed are constantly stressed by heat and voltage and subject to mechanical stresses and corrosion. New materials are needed to better use today's system as well as enable new T&D facilities with increased performance-cost ratios. A white paper prepared for the DOE in April 2003 by ORNL staff scientists describes ten areas of materials R&D needs for the T&D system, including higher strength-to-weight ratio conductors; more reliable sensors; new concepts for dielectric materials; transformer core materials; materials for low-cost, encapsulated switches and breakers; diamond- and SiC-based high-temperature, high-current power electronics; improved arrester performance and reliability; structures such as towers, cross beams, casings, and containers; insulator materials; and capacitors and energy storage materials.
- Present-day electric distribution systems are insufficiently intelligent in their response to faults. Although newer systems determine fault location and provide an alternate path for power, there is little capability for real-time local response to contingencies such as loss of a transmission line or a generator.
- In present-day distribution systems, there is very little control of load, or demand response, and distributed energy resources are prohibited from even regulating voltage. There is a pressing need for a distribution system that can respond to contingencies such as unusual loading, transmission congestion, and line outages. Modeling to assess vulnerabilities, test proposed "improvements," and investigate interdependencies with other energy infrastructures (e.g., rail and oil and gas pipelines) is also needed.

ORNL is well positioned to support this initiative because of its broad capabilities in materials R&D and its expertise in key enabling technologies, including sensors and controls and high-performance computing. ORNL holds a leadership position in superconducting materials R&D and is responsible for a major effort in applied superconductivity for electric power systems. Testing and data collection capabilities (for field tests) exist at ORNL, along with instrumentation and controls capabilities for building and commercial loads.

ORNL also has substantial experience in power system modeling. The full suite of standard power systems modeling tools is in place, including the Power System Simulator for Engineers (PSSE), a model that enables transient stability, load flow, and short circuit analysis. Similar capability exists at ORNL for distribution systems modeling and analysis. Improved modeling features are needed, however, to adequately represent the increasingly complex grid network and operations.

ORNL is also in a position to leverage programs in sensor technologies, sensor networks, large-scale data analysis, information technology, and high-performance computing in building an open analysis center for collaborations between government, industry, and university research. As new technologies are developed and envisioned, the impact of the new research and development can be evaluated using real-time sensor feedback and advanced modeling and simulation of the nation's energy grids.

Objectives and Strategies

Objective 1: *Expand ORNL's capabilities in T&D–related materials and modeling research beyond high-temperature superconductors.*

Strategy

- Propose a materials science research agenda in support of DOE's Office of Electric Transmission and Distribution.
- Engage DOE, the Department of Homeland Security (DHS), and private industry in confirming critical technology needs.
- Develop research partnerships with major U.S. stakeholders including industry, universities, and other national laboratories such as Pacific Northwest National Laboratory (PNNL).

Objective 2: *Establish ORNL project for Interconnection-wide (IW) Energy Management System (EMS) for real-time grid operation and control.*

Strategy

- Evaluate options for data sharing, state estimation, on-line contingency analyses, and voltage collapse monitoring for real-time IWEMS.
- Develop and propose IWEMS project.
- Develop research partnerships with industry and utilities.
- Engage computational science resources at ORNL, including high-speed computing, model development, control theory and communication algorithms, and systems theory.
- Determine how the IWEMS would best be maintained and used in a production mode.

Objective 3: *Establish ORNL research area for power system control information design.*

Strategy

- Determine power system operator information needs for normal, emergency, and extreme emergency conditions.
- Characterize current technology successes and failures in meeting system operator needs. Conduct human factors analysis of options.
- Develop research partnerships with industry and utilities.
- Research new approaches for presenting the full range of required information, from substation switching details to broad system overview and trend spotting.
- Develop laboratory and field test facilities.

Objective 4: *Establish new ORNL thrust area in research and development of low-cost, ubiquitous sensors and communication technologies.*

Strategy

- Establish industrial partners at the outset.
- Collect site / field data on best methods to make and integrate low-cost sensors into the grid.
- Work with local business (Electrotek) to develop methods to integrate data with utilities' system data.
- Develop communication protocols / algorithms.

Objective 5: *Establish new research facilities—the Energy Reliability and Efficiency Laboratory (EREL), the National Transmission Technology Research Center (NTTRC), and the National Energy Assurance Analysis Center (NEAAC).*

Strategy

- Secure construction funding for EREL in FY 2005.
- Develop and propose core program concepts for the NEAAC (National Energy Assurance Analysis Center) effort.
- Identify testing and facility needs to determine functional requirements for the NTTRC in cooperation with DOE, the TVA and other utilities, and industry.
- Obtain designation of NTRRC and EREL as national user facilities.
- Develop a broad outreach initiative along with Web-based tools for proposal evaluation, user training, and allocation of facility and instrument time.

Dedication of the National Transmission Technology Research Center.

Key Partnerships

Partnerships have been established with U.S. manufacturers, energy service providers, national laboratories, universities, and utilities to expand and modernize the grid.

- Key partnerships with U.S. manufacturers include the following:
  - Southwire Company (Carrollton, Georgia), the largest U.S. manufacturer of utility and building wire and cable
  - Waukesha Electric Systems (Waukesha, Wisconsin), the largest U.S. manufacturer of medium-power transformers
  - Carrier Corporation (Farmington, Connecticut), a manufacturer of smart thermostats for small-to-large loads
  - Digi-Log (Maynardville, Tennessee), a manufacturer of equipment for responsive load
- Key partnerships with utilities and energy service providers include the following:
  - Tennessee Valley Authority, the largest public power provider in the United States
  - Southern California Edison and the California Energy Commission, which operate a large public benefits R&D program
  - Duke Energy, Southern Co., American Electric Power (AEP), and Entergy

Other important collaborators are Pacific Northwest National Laboratory (especially their "Grid-Wise" initiative), Virginia Tech, Georgia Tech, and the University of Wisconsin.

Budget Information

The following table provides a profile of projected funding for ORNL research in the four areas covered by this initiative. It is anticipated that significant increases in funding would result in the FY 2005 time frame.

	Fiscal Year Projections (in millions of dollars)				
	2004	2005	2006	2007	2008
DOE-OETD					
Operating	17.58	28.62	38.50	48.33	48.33
Capital	0.42	1.38	1.50	1.67	1.67
Total	18.0	30.0	40.0	50.0	50.0
DOE-EERE					
Operating	24.42	33.38	38.50	38.67	38.67
Capital	0.58	1.62	1.50	1.33	1.33
Total	25.0	35.0	40.0	40.0	40.0
Homeland Security					
Operating	2	4	5	5	5
DOE-EA					
Operating	1	2	2	2	2
Total	46.0	71.0	87.0	97.0	97.0

Science and Technology for a Hydrogen Economy

Strategic Intent and Expected Outcomes

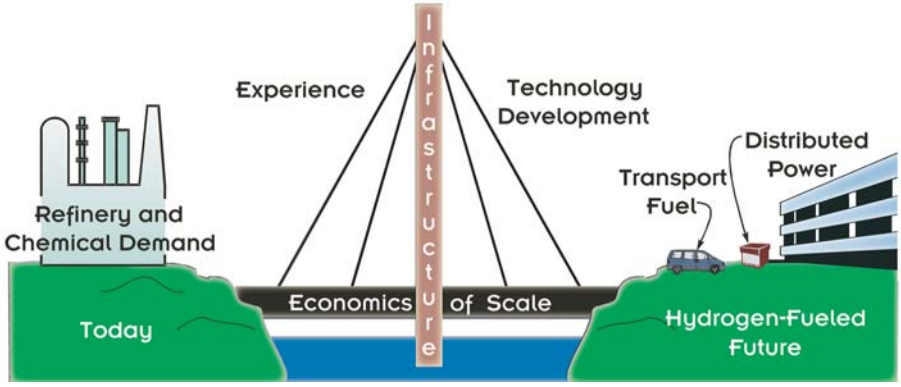
ORNL proposes to deliver new knowledge and technology to overcome the substantial scientific and technological challenges that limit the widespread use of hydrogen as an energy source and to support DOE's Hydrogen, Fuel Cell and Infrastructure Program and the FreedomCAR and Vehicle Technology programs. Our efforts will focus on the following outcomes:

- New low-pressure, high-hydrogen storage capacity materials
- Affordable, clean, and reliable technologies for producing hydrogen from renewable sources
- Very-high-efficiency hydrogen-fueled engine technologies
- Development of a systems-level understanding of the economic, technological, and logistical factors governing the widespread use of hydrogen for transportation, direct residential and commercial applications, and electrical generation

Significance of Outcomes

Hydrogen (H_2), like electricity, is an energy carrier. Any energy source can be used to manufacture H_2, including fossil, nuclear, and renewable energy sources. This is major advantage because different parts of the world have different primary energy sources. Hydrogen when burned yields only water, thus making it the ultimate clean fuel. Although the manufacturing processes used to produce H_2 do generate various types of pollutants, it is significantly easier to control the pollution from a few thousand production facilities than from hundreds of millions vehicles. Lastly, the potential exists for efficient low-cost conversion of H_2 to electricity with fuel cells and electricity to H_2 with electrolysis. Efficient inter-convertibility would allow H_2 to be a stored form of electricity and lower-cost nighttime electricity to be used for H_2 production. While the advantages of a H_2 economy are self-evident, the technical challenges to make an economically viable H_2 economy are significant. It is the successes or failures that are encountered in meeting these challenges that will determine the timing and scope of the H_2 economy.

In recognition of these advantages and the nation's substantial energy and environmental challenges, the administration has established a major thrust to enable the use of H_2 as a fuel. Key objectives of this thrust are hydrogen generation, delivery, storage (both large and small), and utilization in fuel cells. This initiative is intended to contribute substantially to these critical national objectives.



The growing hydrogen demand creates a bridge to the hydrogen economy, with a future hydrogen energy demand that may exceed that for electricity.

Background

Today worldwide H_2 consumption is approximately 50 million tons/year, a small fraction of what would be required for H_2 to be a major part of our energy mix. This production system is supported by major pipelines, underground bulk storage caverns for H_2, and a variety of other specialized facilities, but, again, on a smaller scale than would be required for an H_2 economy.

The characteristics of the world oil-based economy create a near-term H_2-economy option: H_2-enhanced fuels. The adoption of H_2-enhanced fuels would create much of the infrastructure (production, pipelines, and storage facilities) required for a transition to a full-scale H_2 economy. If low-cost H_2 were available, the yield of gasoline, jet, and diesel fuel per barrel of oil could be increased by up to 15% by increasing the H_2-to-carbon ratio in the final product.

In the longer term, some type of H_2-fueled transportation system is likely; however, this could take several forms. Ford has demonstrated that H_2-fueled internal combustion engines (ICEs) will be about 25% more efficient than an equivalent gasoline ICE. In hybrid vehicles, the H_2-fueled ICE has about 50% better fuel economy than the equivalent gasoline-fueled vehicle. The efficiency of H_2 fuel cells is expected to be double that of an equivalent-powered gasoline ICE. The cost of fuel cells must be reduced by a factor of 50 or more to be competitive for automotive applications; however, they are becoming more competitive for specialized industrial markets. These markets will aid the commercialization of fuel cells.

The initial large market for fuel cells will be electricity generation, where the market does not require such severe reductions in fuel-cell costs. The high-efficiency conversion of electricity to H_2 with electrolyzers and H_2 to electricity with fuel cells may make H_2 viable as a form of electricity storage. If this can be achieved, it would create a massive demand for H_2 and result in the development of a large H_2 infrastructure. This benefits high-capital-cost, low-operating-cost energy sources (nuclear and renewable energy sources) by providing a market for energy to produce H_2 in periods of low-electricity demand. Furthermore, large pipelines may provide a means of bypassing the electrical transmission grid bottlenecks that occur during periods of high-electricity demand.

These opportunities define the most important technical barriers that must be overcome:

- **Vehicle onboard H_2 storage.** Most of the prototype H_2 vehicles store H_2 in high-pressure carbon-fiber cylinders. Various solid storage media for H_2 also exist. All of the current options have serious limitations such as excessive weight, large volumes, or complicated refueling schemes. If H_2 is to be reliably used for vehicles, substantially better technologies are needed.
- **Low-cost carbon-free H_2 production.** From a global perspective, low-cost carbon-free H_2 production probably implies nuclear-generated H_2 or steam reforming of fossil fuels with CO_2 sequestration. In the longer term, fusion reactors have potentially very high coolant outlet temperatures, which make them ideal for thermochemical production of hydrogen. While renewables will contribute locally, the required quantities of H_2 are extraordinarily large. Substantial technical challenges must be overcome to make the reformation of fossil fuels economically and environmentally acceptable.

ORNL is well positioned to make a significant contribution to the developing technologies that underpin the hydrogen economy. Areas of particular strength at ORNL that will play a large role include the following:

- neutron scattering as a characterization tool pathway to correlate storage capacity of metallic and carbonaceous materials

- carbon materials research
- alloy design and testing
- inorganic membrane technology
- safety analysis (reliability and lifetime analysis)
- renewable hydrogen production via microbial routes
- novel thermochemical cycles for hydrogen production
- modeling and simulation of systems and materials

Key Accomplishments

- Inorganic Membrane Technology Laboratory (IMTL) transferred to ORNL—August 2002
- Selected by Shell Oil as major partner for H_2 separation membrane development—October 2002
- ORNL performs lead role in road mapping DOE EERE OIT hydrogen activities—April 2003
- ORNL performs lead role in road mapping GEN IV hydrogen separation and thermochemical cycles—April 2003

Objectives and Strategies

Objective 1: *Generation—Establish ORNL as a recognized National Leader in the development of technologies for hydrogen generation and delivery.*

Strategy:

- Establish a leadership role in the GEN IV nuclear program the areas of separations and thermochemical processes.
- Establish the inorganic membrane technology as the top membrane for hydrogen purification through strategic industrial partnerships.
- Develop a lead lab role within the Office of Hydrogen, Fuel Cells and Infrastructure for the transition from fossil-derived to renewable hydrogen

Objective 2: *Storage—Establish ORNL as a recognized National Leader in the development of technologies for hydrogen storage.*

Strategy:

- Develop strategic partnerships with industry, universities, and other national laboratories conducting research on hydrogen storage technologies.
- Lead proposal to establish chemical hydride center of excellence at ORNL.
- Support other lead national laboratories proposing carbon and complex hydride centers of excellences.
- Expand research capability at the National Transportation Research Center (NTRC) to include computer simulation and modeling and safety testing of storage technologies.
- Work closely with the High Flux Isotope Reactor (HFIR) to establish ORNL as a leader in the characterization of storage materials.
- Develop an outreach program focused on bringing industry and universities to ORNL to utilize the user facilities.
- Publish peer-reviewed papers.

Objective 3: *Engines—Establish ORNL as a recognized National Leader in hydrogen-fueled engine efficiency research.*

Strategy:

- Develop strategic partnerships with industry, universities, and other national laboratories conducting research on hydrogen-fueled engines.
- Construct facilities at the NTRC that will enable research on advanced hydrogen-fueled engines.

- Expand research engine capability at NTRC to include variability on parameters such as compression ratio, valve timing, fuel temperature and pressure, inlet air temperature and pressure, combustion process control, etc.
- Expand engine computer simulation and modeling capability for combustion control.
- Conduct experiments to validate approaches to radically improved engine efficiency
- Publish peer-reviewed papers.

Objective 4: *Carbon Sequestration—Establish unique capabilities (facilities and the supporting science and technology) to solve the challenges in carbon sequestration (terrestrial, geological, ocean, and novel systems) that will enable the United States to implement a suite of options with significant capacity and high reliability.*

Strategy:

- Establish a partnership with Battelle in addressing issues in the geological option (e.g., reducing uncertainties in capacity, performance, and leakage rates).
- Perform a detailed analysis of the issues in separation and capture and develop an R&D plan that would result in technologies (e.g., new membranes or materials) that would deliver significant reductions in the cost to separate and capture CO_2 from existing fossil fuel plants.
- Continue leadership in the terrestrial options via Carbon Sequestration in Terrestrial Ecosystems (CSiTE) and complementary projects: (1) complete renovation of the plant genomics facility (Building 1506); (2) develop new partnerships that focus on regional issues of implementation, monitoring, measurement, and verification; and (3) explore linkages in plant genomics with technologies needed in sequestration.
- Expand collaborations in ocean sequestration science to utilize unique capabilities of the seafloor process simulator for non-DOE funding.
- Continue our focus on science (publications) and support to national planning efforts in climate science and mitigation technologies.

Key Partnerships

Original equipment manufacturers and tier-one suppliers recognize the need for research and development of advanced concepts for hydrogen production and storage for the automotive industry. Existing and evolving partnerships include Caterpillar, ChevronTexaco, Cummins, DaimlerChrysler, Ford, General Atomics, GM, and Shell Hydrogen.

Other collaborators are Sandia National Laboratory (California), Florida Solar Energy Research Center, the University of Tennessee, and the National Renewable Energy Laboratory.

Budget Information

	Fiscal Year Projections (in millions of dollars)				
	2004	2005	2006	2007	2008
Total[a]	1250	1700	2300	2800	2300

[a]Funded by Laboratory overhead; no operating or capital funding provided.

Fission to Fusion

Strategic Intent and Expected Outcomes

ORNL will become the major provider of new applications of nuclear science and technologies to supply the power needs of the world and will host one or more new experimental facilities. We intend to do the following:

- Provide the nuclear energy community with technologies that will enable cheaper, safer, enhanced proliferation-resistant, and environmentally acceptable use of nuclear energy.
- Provide the fusion energy community with scientific and technological advances that will enable the commercialization of fusion energy.
- Build and operate experimental facilities at ORNL in support of these missions, building a user support base that enables outstanding science and technology while maximizing the efficient use of the facilities.

Significance of Outcomes

Fission energy and fusion energy, when considered together, offer the prospect of affordable carbon-free electricity and hydrogen for transportation and without the problems that were typically encountered when nuclear science and technology were first applied to energy production.

In nuclear energy (fission), DOE has set goals to have a Generation IV reactor producing electricity and hydrogen by 2020. Meeting this goal will require new technologies that make nuclear energy the technology of choice for future large-scale energy production.

Similarly, the National Energy Policy report recommends that DOE develop fusion as a next-generation energy technology, and the United States has entered negotiations for the construction of the International Thermonuclear Experimental Reactor (ITER) burning plasma experiment as the first major step towards this goal. To meet the time frame required by this initiative, the Fusion Energy Sciences Advisory Committee (FESAC) has developed a road map that identifies key steps and facilities required for the goal of fusion energy demonstration by 2035.

Our success in providing critical technologies and concepts will play a major role in enabling DOE to reach these goals. Building ORNL capabilities will be based upon existing strengths in nuclear science and technology, fusion energy, materials science, and chemical separations.

Background

Both fission energy and fusion energy derive their ability to provide energy from nuclear reactions—nuclear fission and nuclear fusion. The successful application of these nuclear processes to the generation of carbon-free energy offers a practical path to reducing the carbon intensity of the United States, and ultimately the world, economy.

Today's nuclear energy technologies are plagued with economic problems and uncertainties, and concerns associated with nuclear waste have yet to be resolved. In light of these issues, DOE and the national laboratories are developing next-generation nuclear systems, usually referred to as Generation IV systems. In addition, industrial companies are seeking to build demonstration reactors.

At the request of DOE, directors of six national laboratories, including ORNL, have jointly developed an action plan focused on accelerating and enhancing DOE nuclear energy, reactor waste, and nuclear materials management programs. This action plan foresees the construction of a high-temperature gas-cooled reactor to demonstrate nuclear hydrogen production and electricity production, demonstration of an advanced nuclear-hydrogen process technology, expanded international nuclear cooperation, and demonstration of a closed nuclear fuel cycle—all under an extended framework for nuclear materials management.

In January 2003, the President announced that the United States would enter negotiations with several international partners to construct the world's first burning plasma experiment—ITER. ITER will produce sustained fusion powers at the hundreds-of-megawatts level and demonstrate key scientific and technological aspects that will be common to future fusion power plants. ITER is the first major step towards demonstration of fusion energy on a commercial scale. The FESAC has recently issued a comprehensive development path that culminates with an on-line demonstration of fusion energy in a time frame that meets the President's goal of commercialization of fusion power by the mid-century. The FESAC plan identifies several major new facility / project requirements to meet the 35-year plan objectives. These requirements span the complete science-to-technology spectrum of issues, including theory and advanced simulation, configuration optimization, burning plasma physics, and materials and nuclear component testing.

The fusion program is highly collaborative, nationally and internationally. ORNL is a leading U.S. institution with scientists on long-term assisgnments at DIII-D at General Atomics, presently the largest U.S. fusion device, and at many international facilities worldwide. This collaborative nature is an important and integral part of the fusion program; it contributes to the individual growth of scientists and leads to broad exchange of ideas and technologies.

ORNL is ideally suited to contribute to these outcomes. ORNL has a long-standing leadership role in the development of gas-cooled reactor technologies and reactor materials and leads the U.S. effort in developing high-performance radiation-resistant structural materials for the fusion energy applications. Gas-cooled reactors appear to be the only viable candidates for delivering the temperatures required for hydrogen production, a key requirement of a next-generation reactor. In the longer term, fusion reactors utilizing high-temperature structural materials and heat recovery components currently under development (such as SiC composites) will be ideally suited for hydrogen production. ORNL has also played a long-standing leadership role in separations technologies that will be crucial in the development of hydrogen production processes and closing the fuel cycle. In addition, ORNL has a rich tradition of developing innovative magnetic fusion confinement concepts and is a leader in the development of plasma and fusion technologies. Furthermore, there is a strong overlap between the core technologies and their application in both fission and fusion, which will allow ORNL to position itself as a main supplier of core technologies in both cases and allow the United States to benefit from the synergies created. ORNL has also supported previous DOE advanced reactor programs in terms of high-temperature material and coated-particle-fuel technologies.

ORNL has also strengthened facilities and infrastructure to support current ORNL roles in the fusion program and prepare for new opportunities. ORNL's campus revitalization has permitted consolidation of fusion staff and programs at ORNL's main campus. The new location provides high-bay space suitable for test loops and fusion-related experiments and a computational facility design to house world-class computing capable of supporting the Fusion Simulation Project. In the long term, ORNL may be a candidate site for additional experiments and test facilities, as laid out in the DOE and Office of Science strategic plans.

Key Accomplishments

- ORNL has reestablished its capability to fabricate coated-particle uranium-bearing fuels and developed and implemented new characterization methods for the next generation of coated particle fuels.
- ORNL has been selected by the DOE Office of Nuclear Energy, Science and Technology as the National Director for Materials for the Generation IV Advanced Reactors Initiative. As the first step, ORNL has led the development of a materials needs report for the Very-High-Temperature Gas-Cooled Reactor (VHTR) Systems and is currently compiling similar reports for the other Generation IV concepts.
- In a multi-institutional SciDAC project led by ORNL, the first fully resolved two-dimensional calculations of the conversion of fast radio frequency waves to short-wavelength modes in a plasma were obtained. This mechanism is important for driving the internal currents and flows required for maintaining and improving plasma confinement.
- ORNL, in partnership with Princeton Plasma Physics Laboratory (PPPL), developed two variants of a new innovative plasma confinement concept—the compact stellarator. The NCSX and QPS devices combine the best features of the tokamak with those of the other major confinement approach, the stellarator.
- In collaboration with PPPL, ORNL completed an ITER-relevant high-power-prototype radio frequency heating antenna for the JET tokamak in Europe. In collaboration with General Atomics, a new ITER-relevant disruption mitigation technology has been demonstrated.
- ORNL and its collaborators have developed an advanced SiC composite ceramic for fusion energy applications. Unlike commercially available SiC composites that become substantially weaker during neutron irradiation, the strength of the new formulation was shown to improve by 5 to 10% after irradiation in the High Flux Isotope Reactor.

Objectives and Strategies

The development of new technologies and new capabilities will be accomplished through the following objectives.

Objective 1: *Support design of candidate near-term and Generation IV reactors.*

Strategy

- Develop partnerships with and provide key technologies to industrial teams involved in design and construction of candidate near-term reactors.
- Provide DOE with the overall leadership of the Generation IV materials program and provide DOE with the technical expertise for development and qualification of advanced coated-particle fuels.

Objective 2: *Develop next-generation technologies for particle fuel that allow for continuous production of high-quality fuel for Generation IV reactors.*

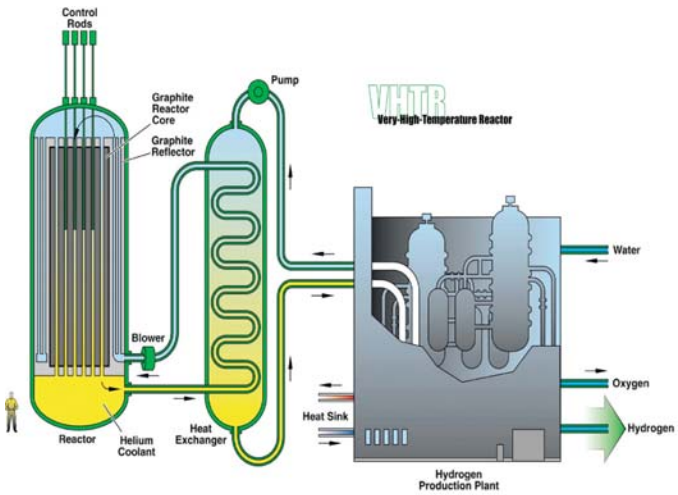
Strategy

- Develop new particle coatings for use at the high temperatures required for hydrogen production.
- Develop next-generation automated fuel inspection technologies to ensure consistent fabrication quality (missing in previous applications) and to reduce cost.

Objective 3: *Develop next-generation technologies for processing of reactor fuel.*

Strategy

- Develop applications of ionic liquids and other innovative processing technologies.
- Support DOE / Air Product & Chemicals, Inc. (APCI) programs in the area of separations.



Very-High-Temperature Gas-Cooled Reactor system.

Objective 4: *Advance the fundamental understanding of plasma science and develop an integrated simulation capability for fusion plasmas and reactors.*

Strategy

- Support DOE's initiative to develop an integrated simulation capability for fusion plasmas and reactors.
- Make strategic investments in key personnel for the Fusion Simulation Project (FSP).
- Develop innovative FSP building blocks.

Objective 5: *Establish the basis for more attractive fusion systems by developing and investigating innovative magnetic confinement configurations.*

Strategy

- Address key scientific issues on national and international facilities relevant to the Advanced Tokamak [DIII-D, Joint European Torus (JET)] and National Spherical Torus Experiment (NSTX) and develop the compact stellarator confinement approach with new facilities [National Compact Stellarator Experiment (NCSX) Quasi-Poloidal Stellarator (QPS)].
- Develop a three-dimensional transport computational tool for advanced stellarator design studies.

Objective 6: *Advance DOE's burning plasma experiment initiative by providing expertise, R&D, and components during the construction phase of ITER.*

Strategy

- Pursue a broadly based burning plasma research program, including simulation, advanced tokamak scenarios, diagnostics, and plasma and fusion technologies in support of ITER objectives.
- Develop plasma and fusion technologies relevant to ITER.

Objective 7: *Develop enabling technologies for the fusion program's research facilities and establish the materials science basis for the fusion energy application.*

Strategy

- Develop plasma heating, fueling, and disruption mitigation technologies to enable creation and control of high-temperature, high-density plasmas.
- Conduct collaborative R&D and modeling on structural materials with attractive safety and environmental characteristics such as SiC / SiC composites, vanadium alloys, and advanced ferritic steels.

- Make strategic investments to position ORNL as a candidate site for a 14-MeV neutron source, such as the International Fusion Materials Irradiation Facility, which is needed for prototypic materials irradiation.

Key Partnerships

- *Nuclear Energy*—Argonne National Laboratory, Idaho National Engineering and Environmental Laboratory, Sandia National Laboratories, Los Alamos National Laboratory, Lawrence Livermore National Laboratory, universities, selected industrial partners, and international partners.

Broad cooperative programs to establish the need for nuclear energy for the future as well as participation in the Generation IV initiative.

- *Fusion Energy Sciences*—Argonne National Laboratory; Pacific Northwest National Laboratory; Princeton Plasma Physics Laboratory; University of California, San Diego; MIT and other universities; General Atomics; Japan Atomic Energy Research Institute; European Fusion Development Agreement; and other international partners.

Broadly collaborative programs to establish the science and technology base for development of fusion as an energy source. This effort spans collaborations on atomic physics, theory and simulation (SciDAC), experiment design and operation (DIII-D, National Spherical Torus Experiment, National Compact Stellarator Experiment, Quasi-Poloidal Stellarator, ITER), and enabling technology and materials development (Virtual Laboratory for Technology).

Budget Information

	Fiscal Year Projections (in millions of dollars)				
	2004	2005	2006	2007	2008
DOE-AT Magnetic Fusion					
Operating	19.2	20.7	21.2	23.9	28.7
Capital	1.8	6.0	6.5	6.5	1.3
Total	21.0	26.7	27.7	30.4	30.0
DOE-AF Nuclear Energy R&D					
Operating	16.6	25.8	26.6	27.4	28.2
Capital	3.8	2.3	0.9	0.9	0.9
Total	20.4	28.1	27.5	28.3	29.1
Total	41.4	54.8	55.2	58.7	59.1

Neutron Science

Strategic Intent and Expected Outcomes

ORNL will become the world's foremost center for neutron sciences, providing unprecedented new capabilities for understanding the structure and properties of materials.

To realize this intent, we will accomplish the following:

- Design, construct, and operate neutron sciences facilities of the highest efficiency and effectiveness for users in the chemical, materials, physical, biological, and engineering sciences.
- Develop and support an international user community with access to world-class instruments and comprehensive support and training programs.
- Apply advanced neutron scattering techniques to yield new knowledge in ORNL's materials, chemistry, life sciences, physics, and applied engineering programs.
- Further the state of the art of neutron scattering instrumentation to enable leading-edge research in these fields.

Significance of Outcomes

Neutron scattering represents one of the most powerful probes of matter, complementary to synchrotron radiation and other available probes. Neutron scattering enables advances in the materials, chemical, and life sciences and in engineering/technology in such crucial areas as electronics and lightweight materials. Cutting-edge neutron scattering capabilities are essential to U.S. leadership in some of the most scientifically exciting and technologically important fields of research and will remain so for decades to come. The combined assets of the upgraded High Flux Isotope Reactor (HFIR) and, following construction, the Spallation Neutron Source (SNS) will provide our nation with the finest neutron scattering facilities in the world.

Instrumentation advances and higher intensity beams will create new opportunities at the leading edge of several fields in science and technology. Improvements on the order of a factor of 10 to 100—in a combination of new facilities and state-of the-art instruments—will encourage research in areas that have previously been limited by the minimum size of samples and the length of time required to collect data. For instance, because of the sensitivity of these new instruments, it will now be much easier to determine the positions of the hydrogen atoms in biomolecules. We also note that the full scientific impact of order-of-magnitude improvements in instrument performance almost always turns out to be broader than anticipated.

By building ORNL capabilities and expanding the use of neutron science, ORNL's materials, biology, and energy technology programs will be strengthened. We anticipate advances in our fundamental understanding of magnetic materials, superconductivity, lattice dynamics, and long-range structure in noncrystalline materials. In addition to the great scientific importance of these areas, these advances will have application in such areas as fuel cell technology, conductors, hydrogen-storage materials, and the design of more efficient motors and power transmissions.

Background

Neutron scattering is used by a variety of scientific disciplines to study the arrangement, motion, and interaction of atoms in materials. Neutron scattering techniques are uniquely effective for probing magnetic materials, for observing small fluctuations in magnetic fields, for measuring vibrations in materials, and for observing the position of light atoms. Thus neutron scattering provides valuable information that often cannot be obtained from other techniques, such as optical spectroscopy, electron microscopy, or X-ray diffraction. These techniques are complementary, and the availability of multiple techniques is essential to a wide variety of research fields.

The capabilities available to U.S. researchers greatly lag behind those available in Europe and Japan. Although excellent work is done at the four existing U.S. facilities [HFIR, Intense Pulsed Neutron Source (IPNS), Los Alamos Neutron Science Center (LANSCE), and National Institute of Standards and Technology (NIST)], our nation lacks leading-edge neutron scattering capabilities and the capacity to support the demands of our scientific enterprise. In consequence, the U.S. community of researchers who are knowledgeable in the use of neutron scattering is small relative to the scientific importance of these tools. A recent National Academy of Sciences report found that "… in some areas, such as neutron scattering, U.S. facilities have not kept up with foreign competition." Indeed, new or enhanced facilities are planned or under way in Japan, Australia, France, England, Switzerland, Germany, and Korea. With the completion of ORNL's SNS in 2006 and the upgrade to the HFIR, the United States will be providing research capabilities in this country equivalent to or exceeding the best in the world.

ORNL is well positioned to deliver these outcomes. ORNL's strengths in neutron sciences constitute an integrated capability that spans programs across the entire Laboratory. The capability dates from the 1940s when Cliff Shull conducted his pioneering research using neutron scattering at the Graphite Reactor, for which he shared the 1994 Nobel Prize in Physics. We are expanding the user program in neutron scattering at HFIR, the highest-flux reactor-based source of neutrons in the United States. Three new state-of-the-art spectrometers have already been brought on-line, and over the next two years, additional instruments will be brought on-line for a variety of materials science and life sciences applications. With the completion of the SNS in 2006 and the expansion of its instrument suite over the next several years, ORNL will be positioned to support a user community in excess of 2000 users each year. Strong partnerships with national laboratories and leading research universities enable us to both build high-value research collaborations and support training of the next generation of principal investigators in modern neutron scattering techniques.

Aerial view of the Spallation Neutron Source.

Objectives and Strategies

The development and continual improvement of cutting-edge neutron scattering capabilities for the scientific community and the development of major new research programs that employ neutron scattering techniques will be accomplished through the following objectives.

Key Accomplishments

- SNS front end commissioned–January 2003.
- SNS Drift Tube Linac Commissioning–August 2003
- Began target installation–April 2003.
- Held third JINS workshop (solid state chemistry and earth sciences)–March 2003.
- Initiated design for disordered materials and inelastic scattering. Funding approved for VULCAN by Canada Foundation for Innovation; MOA signed.
- Installed three world-class triple-axis spectrometers, which are exceeding performance expectations. The installation of three additional world-class instruments is under way.
- Completed construction of the SANS (small-angle neutron scattering) guide hall. Beneficial occupancy is expected by September 2003.
- Implemented formal neutron scattering user program at HFIR, developed jointly with the SNS. The first call for proposals (October 2002) was oversubscribed by a factor of 2.

Objective 1: *Deliver the SNS project on schedule and within budget.*

Strategy

- Maintain the strong partnership among six national laboratories that is required to deliver the SNS.
- Employ a highly disciplined project management approach to meet schedule and budget milestones.

Objective 2: *Upgrade the capabilities of the HFIR.*

Strategy

- Upgrade scientific instrumentation to equal or exceed the current state of the art.
- Install the cold neutron source to provide some of the brightest cold neutron beams in the world.
- Instrument the new guide hall, including world-class small-angle neutron scattering (SANS) capabilities for materials and biological research.

Objective 3: *Establish the basis for the capabilities of the SNS and HFIR to remain at the forefront of world scientific facilities.*

Strategy

- Develop the scientific basis for upgrading the SNS beam power to the 3- to 4-MW range.
- Continue to engage the research community on a planning basis for the Long Wavelength Target Station and its instrument suite.
- Work with physics research communities to include the possibility of hosting instruments studying neutrinos and neutron physics.

Objective 4: *Deliver the next generation of neutron scattering instrumentation at SNS and HFIR.*

Strategy

- Maintain instrument development activities to bring on-line 3–4 instruments per year.
- Support instrument development teams funded by DOE and other agencies.
- Stimulate the design and proposal of new instruments through workshops and other outreach activities.

Objective 5: *Build a world-class user program that provides access to the HFIR and SNS neutron scattering capabilities.*

Strategy

- Develop a joint HFIR-SNS user program to match users to the most appropriate capability for their needs.
- Develop Web-based tools for proposal submission and evaluation, user training, and allocation of instrument time.
- Develop a broad outreach initiative, including an effective training program and a science education program focused on neutron scattering in partnership with a number of research universities.
- Team with other ORNL user facilities to provide single-point access to multiple facilities for researchers requiring use of multiple experimental techniques.

Objective 6: *Establish the Joint Institute for Neutron Sciences (JINS) as an intellectual center for the neutron sciences.*

Strategy

- Obtain design and construction funding for the JINS facility from the state of Tennessee.
- Continue the program of JINS research and instrumentation workshops in additional areas of science.
- Establish JINS programs with universities to train the next generation of scientists and engineers in neutron scattering techniques.
- Obtain core funding for continuing JINS intellectual programs, such as novel concepts for instrumentation and scientific opportunities using neutron beams.
- Initiate hiring process for JINS director.

Objective 7: *Develop innovative research programs at ORNL that take advantage of the unique capabilities afforded by these facilities.*

Strategy

- Invite proposals for ORNL's Laboratory Directed Research and Development program (LDRD) for innovative application of neutron scattering and/or conception of new instruments.
- Support the four SNS instrument development teams led by ORNL research divisions.
- Encourage and expand collaborations by collocating SNS instrument scientists in ORNL research divisions.
- Maintain leadership in the application of neutron scattering to strengthen the user program and drive innovation in science and instrumentation at SNS and HFIR.

Key Partnerships

- SNS Project Team–Lawrence Berkeley, Jefferson, Los Alamos, Brookhaven, Argonne, and Oak Ridge National Laboratories; Knight Jacobs Joint Venture.

  This team is responsible for the design and construction of the SNS.

- JINS with the University of Tennessee.

  Established by ORNL and the University of Tennessee, JINS will serve as the intellectual center for neutron sciences and will promote the use of neutron beam facilities at SNS and HFIR. Its membership, roles, and responsibilities will be further defined and enhanced in the near future.

Budget Information

	Fiscal Year Projections (in millions of dollars)				
	2004	2005	2006	2007	2008
SNS					
Capital (construction project)	143	112.9	74.9	0	0
Operating	0	0	75.0	150.0	160.0
Total	143	112.9	149.9	150.0	160.0

Terascale Computing and Simulation Science

Strategic Intent and Expected Outcomes

It is our intent to become a world leader in harnessing unprecedented computing power as tools of scientific discovery to deliver new insights and achieve breakthroughs with broad impact in U.S. scientific leadership. Thus, we plan to

- develop computer architectures that will dramatically improve hardware performance on scientific problems of importance to DOE;
- develop scientific simulation codes to fully exploit the capabilities of terascale computers for DOE problems; and
- solve outstanding science problems in the areas of Biology, Climate, Energy Assurance, Fusion, Materials, and National Security.

Significance of Outcomes

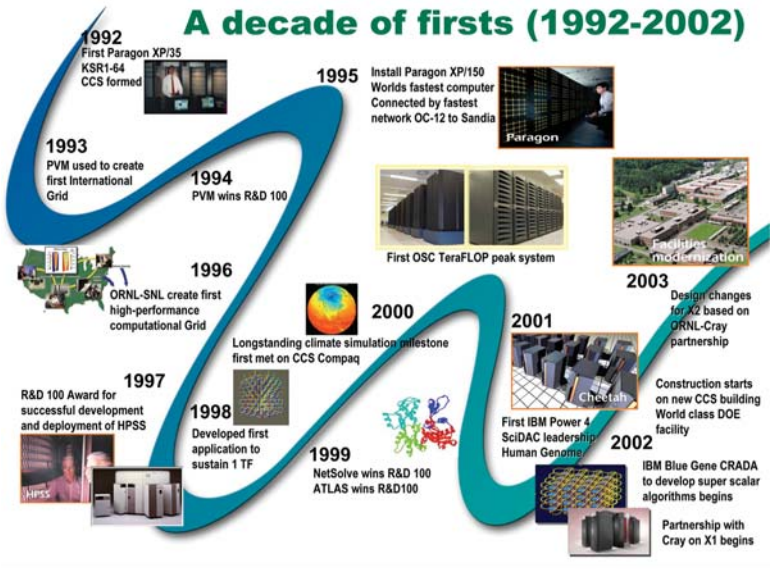
Computing and computational science has emerged as the third leg of scientific discovery in the 20th century. However, the nation's scientists no longer have access to the world's most advanced computing capabilities due to lack of adequate investment in open scientific computing as well as lack of new computing architectures focused on scientific computing. Investments in advanced computing hardware, application software and associated tools, and algorithms and models will result in significant advances in the nation's science capabilities and technology infrastructure and enable the United States to regain its leadership role in computing and computational science. This will lead to significant scientific breakthroughs and impact people's lives. The following table illustrates both the promise and the performance requirements for computational science in the early 21st century.

Application	Simulation need	FY 2004–2005 Computer need (Tflops)	Significance
Climate Science	Calculates energy, water, and greenhouse gas exchanges among the atmosphere (including clouds), ocean, land surface, and sea ice.	>750	Provides U.S. policymakers with leading science information to support policy decisions. Dramatically improve long-term climate predictions, particularly of extreme weather conditions, under changing climate forcings.
Materials	Performs predictive simulations of advanced materials properties and synthesis.	>100	Accelerates 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.

Biology	Predicts the functions and behaviors of complex biological systems beginning with microbes.	>50	Directly contributes to progress in addressing the nation's energy, environmental, and national security missions through the Genomes to Life research program.
Magnetic Fusion Energy	Optimizes balance between self-heating of plasma and heat leakage caused by electromagnetic turbulence.	>50	Underpins U.S. decisions about future international fusion collaborations. Integrated simulations of burning plasma crucial for quantifying prospects for commercial fusion.
Communications and Data Systems	Provides communication network analysis of 10,000+ nodes for command and control.	>50	Provides crucial capability to evaluate information superiority for future combat systems and sensor networks for homeland security.
Energy Infrastructure	Performs simulation of large, complex systems that define critical energy infrastructures.	>100	Provides means for industry, government, and university programs to simulate the complex interactions associated with energy infrastructure.

Background

The mainstream of parallel supercomputing in the United States has for some time been dominated by clusters of commodity shared-memory processors (SMPs). This technology path provides excellent price/performance when measured from the theoretical peak speed, but many applications of strategic importance (e.g., climate, materials, biology and fusion) sustain only a small fraction of this speed. Indeed, over the past decade, the sustained fraction of peak performance achieved by these applications has been falling steadily. Many factors account for this but foremost are the increasing disparity between the speed of processors and memory and the design of processors for commodity applications rather than high-end scientific simulations.



In order to achieve 100+ sustained teraflops of effective performance on a broad cross section of scientific problems, an alternative to the commodity SMP approach must be pursued. This will require identifying, evaluating, and operating a more balanced system architecture as well as the ability to

provision the system with the needed application software models, methods, algorithms, middleware, and tools to take advantage of the hardware.

The Center for Computational Sciences (CCS) was founded in 1991 by the DOE as part of the High-Performance Computing and Communications program and was one of two high-performance computing research centers created in DOE national laboratories. From the beginning, the CCS has had three primary missions: (1) evaluate experimental new architectures to see how they work for the DOE Office of Science applications; (2) work with the manufacturers of these systems to bring them to production readiness; and (3) use these new systems on a few applications that are both important to the nation and cannot be addressed with the conventional computer systems of the day. Indeed, ORNL and the CCS have a long history of evaluating new experimental computer architectures and bringing them to bear on scientific challenges.

The Cray X1 offers particular promise for meeting the challenges described above. The X1 is the first of Cray's new scalable vector systems that offers high-speed custom vector processors, high-memory bandwidth, and an exceptionally high-bandwidth, low-latency interconnect linking the nodes. Cray is the only U.S. manufacturer of multi-terascale systems with these characteristics. For Office of Science research applications, the efficiency of the processors in the Cray T1 is anticipated to be comparable to the efficiency of the NEC SX-6 processors in the Japanese supercomputer, the Earth Simulator, built specifically for climate and earth science applications. Its capability is 5 to 20 times that of current U.S. commodity clusters. A significant feature of the Cray X1 is that it combines the processor performance of traditional vector systems with the scalability of modern microprocessor-based architectures. The X1 is the first vector supercomputer designed to scale to thousands of processors with a single system image. Cray's development path scales to nearly 1 PFLOP/s in the latter half of this decade, while significantly improving the price performance of the technology used.

ORNL is uniquely prepared to evaluate these and other new architectures and bring them into service for the scientific community. In 2002 ORNL completed a new Computational Sciences Building (CSB), providing 170,000 square feet of space to house the Laboratory's computing infrastructure. The centerpiece is a 40,000-square foot computer room with up to 12 MW of power and up to 4800 tons of air-conditioning, the nation's largest computer center for scientific research. The CSB also houses the fiber-optic communications hub for the Laboratory, providing direct access to high-speed, wide-area networks linking ORNL to other major research laboratories and universities. Adjacent to the computer room is a new 1700-square foot visualization facility to help the researchers glean understanding and knowledge from the terabytes of data generated by their simulations.

Objectives and Strategies

Objective 1: *Deliver leadership-class scientific computing capability to the scientific community. At ORNL we contribute to this effort.*

- By 2005 deliver computational performance 50 times greater than now achieved for selected scientific modeling problems.
- By 2008 deliver computational performance 1000 times greater than now achieved for selected scientific modeling problems (petascale).

Strategy

The Cray X-1 is the best U.S. option for such a system, and the Cray partnership offers the best option for leadership-scale computing for the nation.

- Began Cray X-1 evaluation at ORNL in 2003.
- Begin installation of the first leadership class system.
- Improve "delivered" performance by a factor of 50 over FY 2002.

Objective 2: *Deploy leadership-class scientific computing capability to our nation's scientific user community.*

Strategy

The Center for Computational Sciences is a user facility providing multi-teraflop, focused resources on advanced architectures for the key science topics of biology, climate, energy assurance, fusion, materials, and national security. With support from the Office of Science, the CCS will be maintained as a leading center for unclassified scientific computing. In addition, the CCS user facility will be expanded to include leadership-class architectures as rapidly as possible and provide high-quality support (for computer cycles as well as scientific support) to the climate, fusion, materials, and biology communities.

Objective 3: *Build a fully coupled global climate model that provides state-of-the-art computer simulations of the Earth's past, present, and future climate states.*

Strategy

At current model spatial resolution and scientific complexity, a 100-year simulation requires 12.5 days on a 4.5-Tflop machine. Resolution enhancement to resolve eddies and clouds, and incorporation of additional complexity (atmospheric chemistry, terrestrial and ocean biogeochemistry, dynamic vegetation) required for long-term dynamics, requires orders-of-magnitude increase in computing speed. We contribute to this effort by conducting research in

- numerical methods research for atmospheric dynamics,
- parallel algorithm development for next-generation climate models,
- benchmarking and performance characterization of supercomputers for climate simulation, and
- development of hydrologic and biogeochemical process models for simulation of climate feedbacks in the full carbon cycle on decadal to century timescales.

Objective 4: *Build a capability to predict reliably the behavior of plasma discharges in a toroidal magnetic fusion device on all relevant timescales and space scales.*

Strategy

We contribute to this effort through computational modeling and simulation directed towards

- high-power wave heating and plasma control,
- new compact stellarator magnetic confinement configurations (analysis for device design), and
- nonlinear studies of plasma turbulence and turbulent transport in fusion plasmas.

Through these efforts, ORNL proposes to play a lead role in the Fusion Simulation Project—a major FY 2004 DOE initiative.

Objective 5: *Enable extraordinary advances in materials science through use of simulation and modeling to explore spatial and terminal scales not fully accessible to experiment.*

Strategy

ORNL researchers in computational materials science make use of and participate in the development of the most advanced high-performance computing technology—hardware, algorithms, and methods—to perform predictive simulations of advanced materials properties and synthesis in the following areas:

- Phase stability, magnetic and mechanical properties of transition metals, their alloys, as well as artificial heterostructures such as multilayers.
- Electronic and structural properties of ferroelectrics, ceramics, and complex transition metal oxides, as well as other strongly correlated oxides.
- Study of transport, magnetism, and other collective phenomena, as well mechanical properties of low-dimensional nanostructured materials.
- Microstructure evolution and modeling of failure in materials used in radioactive environments (radiation effects) as well as in automotive applications.

Key Accomplishments

- Completed first fully coupled climate simulation using T85 CAM (2002).
- Established OC192 network connectivity (2002): 10 Gbit/s network connection from ORNL through Chattanooga to the Atlanta: GigaPOP (managed by Georgia Tech). This link connects to Internet2 and dramatically enhances communications performance between the university research community and ORNL.
- Expanding Terascale Supernova Initiative: achieved 2- and 3-D hydrodynamics models runs uncovering instability in stellar core shock wave (2002).
- Completed design of quasi-poloidal stellarator experiment using simulations on CCS systems (2002).
- Common Component Architecture (CCA) named number 6 in DOE top 10 science achievements for 2002.
- Received first cabinet of “Phoenix” 3/18/03; 32-processor, liquid-cooled cabinet; 128 GB memory; 8 TB disk (SCCrayX1cab.jpg).
- Encouraging initial results on X1: POP climate code running on 16 processors achieved 35.3 simulation years per day—the fastest on any U.S. computer.
- Optimized spectral ICRF field solver TORIC for high performance computing. Initial version took 12 hours on NERSC Cray with 161 modes; largest 1023 modes solved using 128 cpus and 290 gBytes in 12 hours on Cheetah. Simulation of rf wave conversion in plasma (http:www.csm.ornl.gov/IAO/edRF2-3.html)

Objective 6: *Develop the advanced algorithms and computational capabilities to integrate and analyze genomic data and begin to model complex biological systems in support of DOE’s Genomes to Life Program.*

Strategy

We will contribute to this effort through

- databases and tools for interpreting, managing, and disseminating data and models to the greater biological community;
- integrating of the distributed biology databases into a unified knowledge base for predictive modeling; and
- providing both capability as well as capacity computation.

Our computational work will be very closely integrated with experimental work, as is necessary for a systems approach to biology.

Objective 7: *Establish the Joint Institute for Computational Science (JICS) as an intellectual focus for the computational science community.*

Strategy

JICS will enhance and support research using its leadership-class facilities. Fellowship and sabbatical programs will draw the best computational scientists from institutions all over the world for interactions with the resident staff and user communities. Modern computational, communication, and networking capabilities will encourage interactive scientific and video teleconferencing and provide data acquisition and analysis capabilities for resident scholars and their colleagues around the world. JICS will also foster joint faculty positions between ORNL and its university partners and assist multi-institutional research teams developing new applications involving computational science and other uses of high-performance computers.

Objective 8: *Establish strategic partnerships with laboratories, universities, and vendors.*

Strategy

- Develop partnerships with Office of Science and National Nuclear Security Administration (NNSA) laboratories for exploration of next-generation architectures and development of next-generation simulator tools.
- Broadly engage universities across the nation and region to strengthen research partnerships and support the development of the next generation of computational scientists and engineers.
- Maintain close partnerships with supercomputing vendors to encourage and assist in the development of architectures designed for leading-edge computational research.

Objective 9: *Establish world-class expertise in communications modeling.*

Strategy

The need to simulate large systems of communications nodes is becoming important in several key projects. Our strategy is to build upon a convergence of program needs to (1) make several strategic hires in this area, (2) leverage existing CCS infrastructure, and (3) develop leading-edge software for high-performance communication simulations. This area of expertise is becoming increasingly valuable for our strategic thrusts in national defense and homeland security.

Key Partnerships

Laboratories

- Other SC labs as well as key NNSA labs [Sandia National Laboratories (SNL) and Lawrence Livermore National Laboratory (LLNL)] in collaborative efforts to deliver on Scientific Discovery through Advanced Computing (SciDAC) thrust areas and to define, develop, and deploy homeland security and energy assurance.

Universities

- Regional and national universities (e.g., Vanderbilt, MIT, historically black colleges and universities, and minority educational institutions) for collaborative research, joint proposals, expanded expertise and unique, diverse workforce development.

Vendors

- Cray, Hewlett-Packard, IBM, and SGI for high-end computing for science and engineering, next-generation architectures and platforms, specialized applications thrusts, and high-end visualization.
- Qwest for high-speed networks to link collaborative research partners and to enable massive amounts of data transfer.

ORNL Partnerships in SciDAC

The Scientific Discovery through Advanced Computing (SciDAC) initiative brings together computational resources and expertise of multidisciplinary teams to address and develop the scientific computing software and hardware infrastructure needed to use terascale computers to advance research in basic energy sciences, biological and environmental research, fusion energy sciences, and high energy and nuclear physics.

- *Scientific Applications Pilots* partnership with Argonne (ANL), Brookhaven (BNL), Lawrence Berkeley (LBNL), Los Alamos (LANL), Massachusetts Institute of Technology (MIT), Pacific Northwest National Laboratory (PNNL), the University of Tennessee, University of Utah, Cal Tech, Fermi Lab, General Atomics, Georgia Tech, Indiana University, Lawrence Livermore, Princeton Plasma Physics Lab, Princeton University, Rice University, Stanford Linear Accelerator, Thomas Jefferson National Accelerator Facility, University of Wisconsin, University Center for Atmospheric Research, University of California–San Diego, University of Southern California with application in climate simulation, fusion, and astrophysics.
- *Collaboratories and Networks* partnership with ANL, BNL, LBNL, LANL, MIT, PNNL, University of Tennessee, University of Utah, Cal Tech, Fermi Lab, General Atomics, Georgia Tech, Indiana University, Lawrence Livermore, Princeton Plasma Physics Lab, Princeton University, Rice University, Stanford Linear Accelerator, Thomas Jefferson National Accelerator Facility, University of Wisconsin, University Center for Atmospheric Research, University of California–San Diego, University of Southern California with application in science grid and earth systems grid projects.
- *Middleware & Network Research* partnership with ANL, BNL, LBNL, LLNL, LANL, Northwestern University, PNNL, University of Tennessee, University of Utah, Carnegie Mellon University, Georgia Tech, Indiana University, New York University, North Carolina State University, Old Dominion University, Rensselaer Polytechnic Institute, SNL, SUNY–Stony Brook, University of California, University of California–Berkeley, University of California–Davis, University of California–Los Angeles, University of Maryland, University of North Carolina, University of Colorado, University of Illinois–Urbana Champaign, University of Washington, University of Wisconsin in Network Dynamics, Net100, and SSFnet projects.
- *Scientific Applications* partnership with ANL, BNL, LBNL, LANL, MIT, PNNL, University of Tennessee, University of Utah, Cal Tech, Fermi Lab, General Atomics, Georgia Tech, Indiana University, LLNL, Princeton Plasma Physics Laboratory (PPPL), Princeton University, Rice University, Stanford Linear Accelerator, Thomas Jefferson National Accelerator Facility, University of Wisconsin, University Corporation for Atmospheric Research, University of California–San Diego, Southern Cal in Computer Science (Scalable Systems Software, Common Component Architecture, Performance Science and Engineering, Scientific Data Management, Applied Mathematics, PDE Linear / Nonlinear Solvers and Libraries, Unstructured Grids).
- *Climate Research* partnerships with ANL, LBNL, LLNL, LANL, National Center for Atmospheric Research, PNNL, Clarkson University, Colorado State, Georgia Tech, Georgia Tech Research Corp., Goddard Institute for Space Studies, Iowa State, Princeton, University of Arizona, University of California–Los Angeles, University of California–San Diego, University of Indiana, University of Maryland, University of Michigan, University of Quebec, University of Wisconsin.
- *Chemistry Research* partnerships with ANL, LBNL, PNNL, Ames, Carnegie Mellon University, Michigan State, Ohio State, Oklahoma State, Rice, SNL, University of California–San Diego, University of Georgia, University of Maryland, University of Memphis, University of Michigan, University of Wisconsin–Madison.

- *Fusion Research* partnerships with ANL, LBNL, LLNL, LANL, MIT, Auburn University, CompX Corp., General Atomics, Lodestar Corp., MIT Plasma Science Fusion Center, New York University, PPPL, Princeton University Computer Science, Rollins College, Science Applications International Corporation (SAIC), University of California–Los Angeles, University of Chicago, University of Colorado, University of Iowa, University of Maryland, University of Texas–Austin, University of Utah, University of Wisconsin–Madison, Utah State.
- *High Energy and Nuclear Physics Research* partnerships with BNL, LBNL, LANL, Fermi Lab, SNL, Stanford Linear Accelerator Center, Stanford University, Tech-X, Thomas Jefferson National Accelerator Facility, University of California–Berkeley, University of California–Davis, University of California–Los Angeles University of Maryland, University of Southern California.
- Applied Mathematics cross-cutting partnerships in PDE linear / nonlinear solvers and libraries and unstructured grids.

Ongoing partnerships with Cray, Hewlett-Packard, IBM, and SGI for high-end computing for science and engineering.

ORNL / Sandia Red Storm partnership to develop and deploy Cray H / W and S / W technologies.

Budget Information

	Fiscal Year Projections (in millions of dollars)				
	2004	2005	2006	2007	2008
Operating	30.0	31.0	32.0	33.0	34.0
Capital	1.0	1.0	1.0	1.0	1.0
Total	31.0	32.0	33.0	34.0	35.0

Oak Ridge National Laboratory

Programs

Basic Energy Sciences

Biological and Environmental Research

Advanced Scientific Computing

Nuclear Physics

Fusion Energy

Energy Efficiency and Renewable Energy

Electric Transmission and Distribution

Fossil Energy

Nuclear Energy, Science and Technology

Environmental Quality

Homeland Security

Defense Nuclear Nonproliferation

Summary

Oak Ridge National Laboratory has substantial roles in each of DOE's primary missions. The following pages present our strategy for delivering the greatest possible scientific and technological impact in each of the major DOE research programs that we support.

For each major program, we present our long-term strategic objectives for our contribution; a discussion of ORNL programs in the context of DOE mission goals; our objectives and strategies for strengthening our contributions and mission impact; the support needed from DOE to enable that contribution; a brief summary of recent achievements; and our primary research and development partnerships.

We do believe that one of the great strengths of multidisciplinary, multiprogram laboratories, including ORNL, is the ability to make science and technology connections across organizational, disciplinary, and program boundaries. For example, advances in materials science often lead directly to new technologies that advance DOE's energy and national security missions, while applied mission needs can motivate scientifically important and challenging materials science issues. Similarly, advances in computational science both drive and are driven by research progress in a host of other areas. Therefore, although this section is organized by DOE program office, we have attempted to reflect this synergy in our program descriptions.

Basic Energy Sciences

The fields supported by DOE's Office of Basic Energy Sciences (BES)—materials sciences, engineering, chemical sciences, geosciences, and biosciences—have been central to U.S. scientific and technological leadership, national security, and economic prosperity for decades. Today these fields offer remarkable opportunities for scientific advances and ever greater contributions to meeting national needs in energy production, energy use, and related areas of national security. The operation of national user facilities, a keystone of basic science research programs, is entering a new era with the establishment of new facilities for neutron scattering and nanoscale science as well as substantial enhancement of capabilities in X-ray and electron probes of matter. The coupling of the scientific understanding from these instruments and the availability of new computational tools has resulted in a tremendous expansion of theory, modeling, and simulation activities that should lead to further advances in the understanding of the fundamental phenomena that control our physical world. This science is critical in meeting the needs of the nation and the world for an abundant and environmentally sound energy supply, for more efficient end use of energy in industrial processes and transportation, in restoring and protecting the environment, and in fulfilling a host of other national challenges.

ORNL intends to play a major role in attaining the scientific goals of the BES program and in operating world-class user facilities supported by BES. We have established four strategic objectives for our research programs:

1. Deliver world-class research in the areas of materials sciences and engineering, including nanoscale science, neutron scattering, materials synthesis, soft materials, and computational materials science.
2. Develop molecular-level understanding of chemical processes, with emphasis on catalysis, self-assembly, interfacial phenomena, chemical transformations, and natural systems.
3. Provide advances in the materials and chemical sciences to support the needs called out in the recent BES assessment of "Basic Research Needs to Assure a Secure Energy Future," including fundamental research to support hydrogen production, storage, and utilization; efficient use of fossil energy; development of economical renewable energy sources; and efficient end use of energy in industry, homes, and transportation.
4. Develop and operate, on behalf of the scientific community, state-of-the-art user facilities and instrumentation, including neutron scattering facilities at the Spallation Neutron Source (SNS) and the High Flux Isotope Reactor (HFIR), electron microscopes at the Shared Research Equipment (SHaRE) Collaboration Research Center, and tools for nanoscale materials synthesis and characterization at the Center for Nanophase Materials Sciences (CNMS).

These objectives will be achieved through closely coupled experimental and theoretical research. To conduct this program, we will make extensive use of the current generation of major research and computational facilities at ORNL and other national laboratories, as well as actively contribute to the design of facility and equipment upgrades and the development of new capabilities.

Basic Energy Sciences: Materials Sciences and Engineering

Strategic Objectives

Fundamental materials science and engineering research is an enabling scientific foundation for DOE's energy and environmental technologies, national defense, and a wide range of commercial industries. DOE's BES Materials Sciences and Engineering Program supports fundamental research and user facilities related to condensed matter, materials and engineering physics, and materials chemistry. The strategy of the BES program is to support excellent science and the best scientific facilities for materials research. Two recent studies provide the underlying guidance for these efforts: "Basic Research Needs for a Secure Energy Future" and the "20-year BES Facilities Roadmap." Earlier studies on nanoscale science and technology and a number of assessments related to neutron, X-ray, and electron beam user facilities are also guiding the program.

ORNL will contribute to these programs by maintaining a comprehensive fundamental research effort, operating world-class user facilities for neutron characterization, electron microscopy, and nanoscale science; building research teams that are integrated across disciplines and organizations within ORNL; and proactively identifying scientific opportunities that will impact national scientific and technological needs.

1. Our research will support major strategic directions in BES Materials Science and Engineering, including neutron scattering, nanoscale science, computational materials science, soft materials, and synthesis science. Some of the most exciting scientific opportunities will likely span several—or even all—of these research areas. We will give particular emphasis to the ability to synthesize structures with useful properties from a firm scientific foundation.
2. ORNL is uniquely positioned to respond to the recent BES assessment of "Basic Research Needs to Assure a Secure Energy Future." Materials research needs are a dominant theme throughout the report for such areas as support to hydrogen economy, solar energy, fusion energy, next-generation fission energy concepts, fossil energy, and improved energy efficiency. We will build on the strong relationships between ORNL's BES research programs and the mission-oriented research supported by DOE's Offices of Energy Efficiency and Renewable Energy; Fossil Energy; Nuclear Energy, Science and Technology; and Fusion Energy to formulate research programs that will meet these needs.
3. As part of the BES mission to provide national user facilities, ORNL is developing world-class user facilities and will operate effective and productive user programs. For the neutron scattering user community, the SNS and the upgrades to HFIR will be completed (see Neutron Sciences Initiative). These facilities will provide the most advanced neutron scattering instrumentation in the world, with beams that equal or exceed the best available at any other location. The completion of the CNMS will offer advanced synthesis, characterization, and computational tools to the rapidly growing national nanoscale science and technology research community. In electron beam characterization, a critical tool for nanoscience, the completion of the Advanced Materials Characterization Laboratory (AMCL) will provide high-quality housing for our advanced electron microscopes. Participation in the Transmission Electron Aberration-Free Microscope (TEAM) project, a multilaboratory collaboration, will develop the next-generation electron microscopes for the SHaRE User Program.

Overall, our scientific program will include closely integrated experimental, characterization, and theory / modeling / simulation research. The research teams will bring together the cross-

disciplinary expertise required and will involve partnerships with the academic community and other national laboratories. Interactions with the DOE mission–supported and industrial research staff will ensure continuity from basic and applied research to applications that have a technological and economic impact.

Primary Roles in the Context of DOE Mission Objectives

In condensed matter sciences, research will push the frontiers of nanoscience, emphasizing thin films, carbon nanostructures, correlated electron materials, self-assembly, systems with low dimensionality, and cooperative phenomena. Science-driven synthesis will be an emphasized, as it relates to both nanoscience and the needs of the broader scientific community for new materials with well-controlled structures. A critical area for expansion is in the theoretical and computational research that relates to these experimental programs. Development and application of leading-edge characterization techniques will continue, especially in the area of subangstrom scanning transmission microscopy and the scanning probes that are critical to nanoscience. Growth of new neutron scattering research areas is critical as new capabilities come on-line at HFIR and the SNS. New research opportunities will also be pursued to take advantage of the development of submicron three-dimensional X-ray scattering probes.

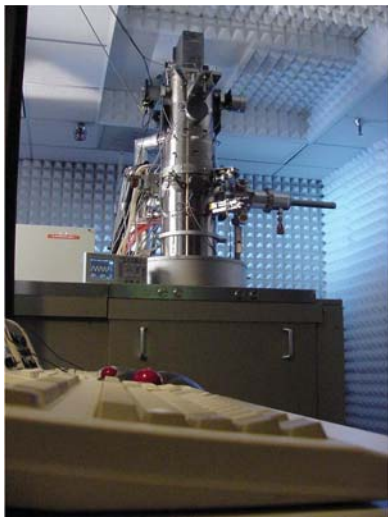
In the Materials and Engineering Physics Program, research on advanced materials will emphasize materials science as it relates to aggressive energy environments, advanced fabrication and materials processing, and the development of material theory and modeling. Research will also focus on improving the mechanical and functional properties of materials in ceramic, intermetallic, amorphous, and other advanced materials systems. Areas of advancement will include lightweight materials, materials that can survive high temperatures and hostile environments, and new functional materials for sensors and other probes. Studies in nanoscience will expand understanding of synthesis and phenomena such as nanofriction and of bulk nanomaterials systems. Computational materials science efforts will include alloy, ceramic, and functional materials theory; nondestructive analysis; molecular dynamics; and process modeling, including friction stir welding. New neutron scattering research will focus on fundamental mechanical properties and hydrogen energy systems. In the SHaRE program, electron and atom probe characterization will incorporate newly evolving techniques and instrumentation, including that developed through the TEAM project. Ensuring that the user community has adequate access to ORNL's scanning transmission electron microscopy (STEM) instrumentation is critical to the program.

The Materials Chemistry Program will focus on soft materials research, emphasizing polymers and polymer blends. Inorganic chemistry, another strength, will include synthesis of nanoparticles. This program will also feature future research in biomaterials. With the Radiochemical Engineering Development Center (REDC), HFIR will also continue to provide needed radioisotopes, predominantly the isotopes of transuranium elements and portable neutron sources using ^{252}Cf for applications in industry, medicine, and national security.

ORNL contributes to several major BES program areas in the field of materials science.

Subprogram	ORNL Role
Experimental Condensed Matter Physics	Thin film and nanostructured materials physics. Synthesis and properties of superconductors and novel materials. Electron microscopy of materials. Synthesis of nonequilibrium materials and structures using laser molecular beam epitaxy. Emergence of nanoscale cooperative phenomena. Low-dimensional materials. Correlated electron materials.
Theoretical Condensed Matter Physics	Theory of condensed matter physics
X-ray and Neutron Scattering	X-ray research using synchrotron radiation. HFIR Center for Neutron Scattering. Structural properties of materials using X-ray diffraction. Mesoscale dynamics and microstructural evolution. Development of neutron scattering instrumentation: cold neutron chopper spectrometer; disordered materials diffractometer; single-crystal diffractometer; high-pressure diffractometer; high-resolution chopper spectrometer; and high-resolution, direct-geometry time-of-flight chopper spectrometer.
X-ray and Neutron Scattering Facilities	Facility operation and research: SNS, HFIR, REDC (radioisotopes and transuranium element processing).
Materials Chemistry	Chemistry of advanced inorganic materials. Structure and dynamics of advanced polymers and nanophase blends. Advanced ceramics and thin films. Structure and properties of chain molecule systems under shear. Nucleation, growth, and transport phenomena.
Structure and Composition of Materials	Theoretical studies of metals, alloys, and ceramics. Microscopy and microanalysis. Atomistic mechanisms in interface science—direct imaging and theoretical modeling. SHaRE User Program.
Mechanical Behavior of Materials and Radiation Effects	Theoretical studies of metals, alloys, and ceramics. High-temperature alloy design. Microstructural design of advanced ceramics. Acoustic harmonic generation by microstructures.
Physical Behavior of Materials	Domain structure and dynamics in epitaxial oxides. Semiconductor nanocrystals for carbon dioxide fixation
Synthesis and Processing Science	Science of nonequilibrium processing of materials. High-temperature alloy design. Acoustic harmonic generation by microstructures.
Engineering Research	Nanofriction. Design and synthesis of nanomaterials. Engineering research related to materials theory/modeling, ceramics processing, and friction welding.
Nanoscience Centers	CNMS

Objectives and Strategies



ORNL's aberration-corrected electron microscope has achieved the world's best resolution (0.7–0.8 Å).

Objective 1: *Become the premier laboratory for neutron scattering research (for additional details, see the Neutron Sciences Initiative).*

Strategy

- Deliver the SNS, including completion of the instrument suite.
- Complete the HFIR upgrade, including installation of the cold source.
- Complete neutron scattering instrumentation upgrades for HFIR.
- Cultivate the internal and external community for neutron scattering through investment of Laboratory Directed Research and Development (LDRD) funds; workshops (in partnership with universities and other national laboratories); and promotion of the field through educational outreach, professional societies, and publications.

Objective 2: *Complete the construction of the CNMS and initiate the user program (for additional details, see the Advanced Materials Initiative).*

Strategy

- Deliver the CNMS facility and associated technical equipment.
- Initiate a dynamic user program and publicize it through appropriate venues and presentations.
- Continue to work cooperatively with the other DOE nanoscale science research centers to develop a successful national nanoscale science user center activity.
- Advance the internal nanoscience research effort through partnerships, investment of LDRD funding, and strategic hires.

Objective 3: *Build capabilities and the underpinning research programs required for science-driven synthesis.*

Strategy

- Develop improved techniques for materials synthesis that optimize control and monitoring of the process.
- Establish new science programs that foster this approach to synthesis, particularly in nanoscience.
- Partner with university programs to increase graduate student involvement in this technical area.

Objective 4: *Establish an expanded research effort in soft materials.*

Strategy

- Establish soft materials as a core element of ORNL's Advanced Materials Initiative.
- Promote research in the interface between soft and hard materials, particularly as it relates to biomaterials.

Objective 5: *Develop a comprehensive computational materials science program.*

Strategy

- Expand existing theory efforts to build stronger programs in nanoscience, soft materials, and neutron scattering.
- Develop theory, modeling, and simulation techniques that bridge length scales.
- Continue to foster strong partnerships with the computational research supported by the Office of Advanced Scientific Computing Research. Collaborate with the university community.

Objective 6: *Broaden ORNL's leadership role in basic research for a secure energy future.*

Strategy

- Use LDRD funding to broaden existing energy-related programs to include new directions identified in the Energy Security workshop.
- Work with DOE and the technical community to establish the support for a national initiative in this area.

Recent Accomplishments

ORNL has completed several milestones related to the CNMS:

- FY 2002: completed 60%, secured $25M in FY 2003 construction funding, obtained conceptual design (CD)-1 and CD-2 approval;
- February 3, 2003: received CD-3 approval (construction contract to be awarded by June 30, 2003); and
- FY 2003: initiated user program with existing facilities and expertise.

ORNL organized the DOE Nanoscale Science Research Centers Workshop for BES.

Aberration-corrected 300-kV STEM has achieved the world's best resolution (0.7–0.8 Å)

As lead collaborator, ORNL presented a successful TEAM proposal to BES for next-generation electron microscopy (involved three other national laboratories and the University of Illinois at Urbana-Champaign).

Capabilities

ORNL has extensive research capabilities in materials science and engineering, condensed matter physics, and materials chemistry. These capabilities have resulted in significant advances in neutron scattering, theory of magnetism, analytical microscopy, intermetallics research, ceramic science, welding science, superconductivity research, synchrotron X-ray research, thin film science, nanoscience, correlated electron materials, and polymer science.

For the international user community, ORNL operates the HFIR (world's highest thermal neutron flux), the SHaRE Program, and beam lines at the National Synchrotron Light Source (NSLS) and at the Advanced Photon Source. New user facilities under development are the SNS and CNMS.

Several new and expanded capabilities will have an impact on science, technology, and user activities:

- subangstrom STEM with single-atom detection capabilities;
- local electrode atom probe;
- three-dimensional submicron X-ray diffraction;
- wide range of neutron scattering instrumentation; and
- novel materials synthesis and fabrication tools, including new capabilities in nanofabrication, friction stir welding, and combinatorial methods for producing novel oxides.

Operational and Support Needs

Completion of the HFIR upgrades and continued reliable operation of the HFIR are critical to our programs in neutron scattering, materials irradiation, and isotope generation. The safe and successful construction of the SNS and the attainment of the subsystem operational goals are likewise critical programmatic requirements.

Much of the basic materials research at ORNL is located in facilities that are 40 years old. Completion of the CNMS and the AMCL will provide much-needed upgrades for part of the research activities, but continued renovations, particularly in the 4500 complex (materials physics and materials chemistry) and the 3025 area (condensed matter physics), are essential to the future of the research activities. These renovations need to bring the facilities up to the standards for modern laboratories by enhancing the reliability of electricity and other utilities; eliminating inefficient once-through water cooling systems; replacing contaminated laboratory furnishings and ductwork; and improving environmental control for temperature, humidity, and stray fields. The existing conditions have a negative impact on the quality of the research and limit our ability to install state-of-the-art analytical equipment. Flexible laboratory space is essential to meet the needs of our basic materials research efforts.

Resolution and improvement of user access are critical to the success of the user programs. The process must be streamlined as much as possible while meeting the necessary security requirements.

Key Partnerships

Partnerships are an integral part of our materials sciences and engineering research programs. For example, the development of new neutron scattering instrumentation and the efforts to expand the neutron scattering user program involve all of the DOE neutron scattering facilities [ORNL, Argonne National Laboratory (ANL), and Los Alamos National Laboratory (LANL)], as well as scientists at Brookhaven National Laboratory (BNL) who are involved in neutron scattering. There is substantial involvement of the neutron scattering experts at universities, as well as those at neutron scattering facilities in other parts of the world. Workshops will continue to provide extensive input on the directions of the science and on instrumentation development.

As a cooperative venture, ORNL, Lawrence Berkeley National Laboratory (LBNL), ANL, Sandia National Laboratories (SNL)/LANL, and BNL are pursuing the construction and operation of the DOE Nanoscience Research Centers. The scientific agenda for the centers has involved universities, other federal laboratories, and industries.

DOE electron beam characterization facilities at ORNL, ANL, LBNL, and the University of Illinois at Urbana-Champaign, as well as with BNL, are in collaboration on the development of TEAM. Users of electron microscopes from a wide range of institutions were involved in the workshops leading up to the recent TEAM proposal.

Basic Energy Sciences: Chemical Sciences, Geosciences, and Biosciences

Strategic Objectives

Fundamental studies in the chemical sciences are providing revolutionary new insight into the atomic- and molecular-level processes that occur in solution, in the gas phase, on surfaces, and at interfaces. This knowledge is enabling new capabilities that are central to many of DOE's missions in energy production, storage, and conservation; environmental restoration and pollution prevention; and national security. In a recent report, "Basic Research Needs for a Secure Energy Future," chemistry is a central component of the identified research needs, because it can elucidate molecular processes involved in catalysis; hydrogen production, storage, and utilization; and improved efficiencies in fossil and bioderived energy. In addition, chemistry will be an important part of nanoscale science and technology, another major emphasis within the DOE BES program. For example, chemistry is key to understanding the molecular-level processes involved in separations that occur at the interface of a nanoporous membrane and a solution. The chemical sciences program at ORNL is well positioned to be a major contributor to these research areas, drawing upon the unique combination of our core capabilities in synthesis, characterization, and computation, along with neutron scattering capabilities and the CNMS.

In our Basic Energy Sciences, Chemical Sciences, Geosciences, and Biosciences Program, we intend to emphasize the following: catalysis and chemical transformations; separations and analysis; heavy element chemistry; geochemistry; chemical energy and chemical engineering; and atomic, molecular, and optical sciences.

1. Our research will support major strategic research directions in BES. Research in areas related to energy, particularly catalysis, will expand. Our program will also be active in nanoscale science and the associated research program at the CNMS, addressing areas such as understanding molecular processes responsible for weak interactions involved in self-assembly, interfacial phenomena occurring at liquid–solid interfaces, chemical transformations at surfaces (i.e., catalysis), and other areas. Theory, modeling, and simulation will be tightly coupled with our experimental program, taking advantage of ORNL's expanding computing resources.
2. Neutron-based techniques provide an important new characterization tool in our research, and expansion of the application of neutron scattering to the chemical sciences is being actively pursued. Enhanced activities are anticipated at the upgraded HFIR and the SNS, where we are involved in establishing instrumentation specifically designed for chemical studies. These techniques can provide new types of molecular-level information, particularly regarding condensed phases.
3. We will create advanced capabilities to serve the scientific community. Our chemical sciences program is helping lead the development of the ORNL CNMS. This national user facility will provide state-of-the-art capabilities for synthesis, characterization, and computation that will enhance understanding of molecular-level processes. In addition, the Multicharged Ion Research Facility (MIRF) provides beams of multicharged atomic and molecular ions in order to study their interactions with surfaces, photons, electrons, ions, atoms, molecules, and molecular ions. REDC, together with the HFIR, provides a range of radioisotopes, predominantly isotopes of transuranium elements and ^{252}Cf for portable neutron sources and applications in industry, medicine, and national security.

Primary Roles in the Context of DOE Mission Objectives

The Catalysis and Chemical Transformation research area has been designed to be a coordinated program incorporating chemical catalysis, surface science, and the chemistry of complex organic energy resources. The catalysis program is a key emphasis area within our chemical sciences program and a focus area within the CNMS. Our work will emphasize the tailored synthesis and characterization of catalytic materials; elucidation of molecular-level processes that occur during chemical transformations at catalytic centers; and theory, modeling, and simulation of catalytic processes. Research activities in this area will provide new molecular-level knowledge of the chemical structure and reactivity of fossil and renewable energy sources, drawing upon unique capabilities in high-temperature reactions at model surfaces, optical spectroscopy, nuclear magnetic resonance (NMR), and computational chemistry.

Heavy Element Chemistry research at ORNL will continue to center on the chemistry of transuranium elements and compounds, with particular emphasis on obtaining a fundamental understanding of electronic configurations, interactions, and energy levels in these materials. Investigations will include high-pressure and high-temperature structural studies, optical characterization, and gas-phase metal ion reactions of heavy elements and compounds. A Fourier transform ion cyclotron mass spectrometer has recently been configured to provide a unique capability to study the gas-phase reactions of heavy element ions. This research has a close tie to the HFIR, which produces heavy elements.

Research in Separations and Spectroscopy focuses on elucidation of fundamental processes that are the foundation of chemical separations and analytical spectroscopies. Principles of separation by chemical recognition and transport phenomena in extractive separations will include synthesis of novel computationally designed ligands and elucidation of the relationship between ligand structure, ionic recognition, and selective separations. Fundamental studies of sampling, ionization, and energy-transfer phenomena that will enhance the type of chemical information available via mass spectrometry continue to be a special focus of this program. Research in laser spectroscopy will emphasize spectroscopy at interfaces and in microdomains to provide highly selective and specific probes of chemical processes.

ORNL contributes to several major BES program areas in the field of chemical sciences.

Subprogram	ORNL Role
Catalysis and Chemical Transformation	Elucidation of chemical reactions at interfaces, including kinetic and thermodynamic studies. Designed nanostructures to probe chemical reactivity, integrated with theory, modeling, and simulation (TMS). Unique solid-state NMR, atomic resolution STEM, synchrotron-based extended X-ray absorption fine structure spectroscopy (EXAFS).
Heavy Element Chemistry	Fundamental studies of electronic configurations, interactions, and energy levels in heavy elements. Unique facilities for synthesis and high-pressure and gas-phase studies of transuranics, including unique Fourier transform ion cyclotron resonance mass spectrometer.

Separations and Spectroscopy	Establishment of principles involved in chemical recognition and separations, including computational design and synthesis of tailored ligands. Elucidation of chemical and physical processes involved in the formation, manipulation, and analysis of ions by mass spectrometry (MS). Specialty instrumentation, such as on-line electrochemistry–MS, large-field organic MS/MS microprobe, quadrupole ion trap ion-ion reaction MS, and others, combined with TMS. Optical spectroscopy to study chemical properties at interfaces and in microdomains. Single-ion/atom and nanostructure optical phenomena via spectroscopic probes.
Energy and Chemical Engineering	High-temperature aqueous chemistry. Experimental and theatrical studies linking intermolecular interactions to macroscopic properties, including separations, weak interactions, and self-assembly. Separation phenomena involving ionic liquids, multiphase systems, supercritical fluids, and nanophase materials. Elucidation of chemical processes that occur in conversion of light energy into chemical energy by photosynthesis. Unique tools include neutron scattering, heat-flux calorimetry, in situ high-temperature pH and volatility measurements, isopiestic (vapor pressure) facility, and combined imaging and spectroscopic probes of interfacial structures.
Geochemistry	Fundamental studies to allow understanding and quantitative modeling of geological processes at the molecular level. Studies of aqueous–metal oxide interfaces, particularly the electrical double layer, at the nanoscale level. Isotope ratio mass spectrometry and vibrating-tube densitometer measurements are among the key capabilities.
Atomic, Molecular, and Optical Sciences	Physical and chemical studies to understand and control matter at the atomic level via studies of scattering induced by interactions of ions with surfaces, matter, and plasmas. The MIRF produces tailored beams of atomic and molecular ions. New physical models established based on novel mathematical and computational techniques coupled with experiments.
REDC	Specialized facilities and expertise for separation of radioisotopes, predominantly isotopes of transuranium elements and ^{252}Cf for portable neutron sources and applications in industry, medicine, and national security. Closely coupled with the HFIR.
Nanoscience Center	The ORNL chemical sciences program, together with the materials chemistry program, leads activities based within the ORNL CNMS. These activities are designed to yield nanoscale understanding and control of chemical processes, including catalysis, interfacial phenomena, weak interactions, and others. Includes specialized facilities for synthesis and characterization of hard (inorganic), soft (organic, polymer, biological), and hybrid (hard/soft) materials
Neutron Science	The ORNL chemical sciences program is leading or participating in the development of several chemistry-driven instruments at SNS and HFIR, including disordered materials diffractometer (NOMAD), vibrational spectrometry (VISION), and several elastic scattering instruments.

In the area of Chemical Energy and Chemical Engineering research, we will combine experimental and theoretical tools to study chemical and thermophysical phenomena associated with interactions at interfaces and between molecular species. In particular, fundamental studies will focus on understanding aqueous chemistry at high temperatures and the interactions of ions in solution. Fundamental studies will be conducted to attain an integrated understanding of separations from the molecular scale to the macroscale. We will also focus on obtaining a fundamental understanding of the principles of conversion of light energy into chemical energy, as conducted during green plant photosynthesis, including the molecular-level understanding of interfacial electron-transfer reactions.

At the ORNL Multicharged Ion Research Facility (MIRF), Electron Cyclotron Resonance (ECR) ion source–based AMO (atomic, molecular and optical) studies are carried out on ion-surface, electron- and ion-atom, molecule interactions. A facility upgrade currently in progress will extend interaction energies by four orders of magnitude.

The ORNL Geosciences research program will investigate fundamental chemical and physical parameters associated with mineral–fluid interactions to gain knowledge that will ultimately permit understanding and prediction of contaminant migration; effects of carbon dioxide injection as a means of carbon sequestration; and processes involved in oil, gas, and geothermal resource formation. This program is also designed to provide nanoscale-level understanding of the structure and properties of the interface between aqueous solutions and metal oxides.

Within the Atomic, Molecular, and Optical Sciences program, research is centered on understanding, and ultimately controlling, matter on the atomic scale via investigation of the interaction of atomic particles from solid surfaces, from penetrating matter, or in gaseous or plasma states. Improvements will be made at the MIRF to permit new regimes of interaction energies and provide an expanded and improved range of ion beams.

The REDC will continue the heavy element program (supported as part of the BES program), as well as the MK-42 program (funded by DOE Defense Programs) and the Advanced Fuel Cycle Initiative (DOE Nuclear Energy). The ^{238}Pu program, which began in FY 2003, is projected to accelerate its operations over the next 2 years.

Objectives and Strategies

Objective 1: *Become a leading catalysis research center.*

Strategy

- Expand catalysis research, particularly in understanding, controlling, and modeling chemical reactions at well-defined catalytic sites.
- Expand interactions with collaborators at universities and in industry.
- Inaugurate a catalysis research focus area as part of the CNMS, developing a user community for catalysis within the Center.

Objective 2: *Establish ORNL as a leader in chemical research within nanoscale science.*

Strategy

- In partnership with the BES Materials Chemistry Program, establish a strong chemistry component within the CNMS, with particular emphasis on understanding and prediction of molecular-level processes with applications in catalysis, self-assembly, interfacial science, and other nanoscience areas.
- Initiate a strong user program within the CNMS, and expand partnerships with universities and others.

Objective 3: *Expand research in areas related to BES initiatives in Hydrogen/Secure Energy Future.*

Strategy

- Utilize LDRD funding to encompass new directions identified in the recent Energy Security and Hydrogen workshops. Particular emphasis will be given to building programs in hydrogen production, storage, and usage (particularly fuel cells) and in increased efficiency in fossil and bioderived energy.

Objective 4: *Expand the computational chemistry program.*

Strategy

- Closely couple theory, modeling, and simulation (TMS) with experimental studies across the chemical sciences program, especially in growing areas of catalysis and nanoscience.
- Foster strong partnership with computational research supported by the Office of Advanced Scientific Computing Research and with the university community.

Recent Accomplishments

Effect of Pressure and Fluid Composition on Isotope Partitioning: A detailed, systematic experimental and theoretical study involving brucite [$Mg(OH)_2$] and water demonstrated that pressure is as important a variable as temperature in controlling isotopic partitioning in some geologic settings.

Photonic "Polymers": Artificial molecules with novel structural and optical properties were assembled by sequential particle attachment. These molecules can be produced with a wide variety of three-dimensional architectures that have important applications in microscale and nanoscale optical areas.

New Insights into Pyrolysis Mechanisms for Aryl Ethers in Lignin: The fundamental reactions that lead to the complex array of pyrolysis products for lignin remain poorly understood. The pyrolysis of several β-aryl ether model compounds constrained to a silica nanoparticle surface has revealed a new impact of mass transport limitations on the mechanism and selectivity for formation of commercially valuable aromatic chemicals.

Effect of Metal-Support Interactions in Catalytic Systems: Elementary adsorption and dissociation steps occurring on a metal particle (e.g., platinum and rhodium) can be altered by the oxidation state of a reducible support (e.g., cerium oxide) upon which it rests. These results advance our understanding of the basic chemical processes occurring within emission control and other catalysts based upon reducible oxide supports.

Insights into Actinide Bonding Provided by Pressure-Induced Changes in Protactinium: Investigations have provided important insights into the electronic behavior of protactinium as a function of interatomic distances. Because of the unusual structures (and physicochemical properties) displayed by the U-Pu elements, pressure can force protactinium and americium to mimic structurally uranium and plutonium.

Density Dependence of the Dielectric Constant of Water: The density dependence of the dielectric constant of water, both in bulk solvent and in locally dense regions near ions in solution, has a strong effect on ion association. The partial dielectric screening of the electrostatic charges of the ion pair allows for a wide range of degree of dissociation as water goes from steam-like to liquid-like densities.

Objective 5: *Establish ORNL as a leader in application of neutron sciences in chemistry.*

Strategy

- Contribute to the establishment of instrumentation at SNS, and demonstrate the utility of neutron scattering and other neutron-based techniques for chemical studies.
- Expand collaborations with universities and other partners.

Objective 6: *Expand chemical research at the interface with biology.*

Strategy

- Identify LDRD funds and critical hires to broaden existing programs in catalysis, hydrogen production, and nanoscience to incorporate molecular processes that employ or mimic biological systems.

Objective 7: *Sustain leading research program in heavy element chemistry.*

Strategy

- Expand capabilities in heavy element chemistry by strategic hires.
- Initiate partnerships with universities to expand collaborations and to train scientists in both heavy element and nuclear chemistry.

Capabilities

ORNL has a core scientific research program in chemical sciences and geosciences that has had major impacts in mass spectrometry, optical spectroscopy, high-temperature aqueous chemistry, geochemistry, energy transformation, separations, and heavy element chemistry. Many specialized capabilities have been developed as part of this basic research program, including facilities for heavy element chemistry, equipment for high-temperature / high-pressure solution chemistry, and unique mass spectrometers and laser-based optical instrumentation. The program shares responsibility for oversight of an XAFS instrument located at the NSLS and also provides the international user community with special capabilities for production of tailored beams of atomic and molecular ions at the MIRF. The REDC provides specialized facilities and expertise for separation of radioisotopes, predominantly isotopes of transuranium elements and ^{252}Cf for portable neutron sources and applications in industry, medicine, and national security.

Operational and Support Needs

The chemical sciences research program at ORNL is located primarily in 40-year-old facilities within the main 4500 complex. While fundamentally well constructed, these facilities are in critical need of renovation to meet the requirements of modern chemical research activities. In particular, upgrades to HVAC systems in these buildings are critically needed to decrease costs associated with heating and air-conditioning and to control temperature and humidity as required by modern instrumentation. Chemical fume hoods must also be updated to meet current ES&H requirements and to improve operational efficiency. Electrical capacity must be increased to meet requirements of modern instrumentation and regulatory guidelines. Finally, waste-handling systems (drains) need improvement to meet environmental requirements.

Key Partnerships

The chemical sciences program collaborates with more than 20 universities and colleges, other national laboratories, and private industry. Many of these collaborations exist with the international community, especially in the area of heavy element chemistry. The development of new neutron scattering instrumentation and the efforts to expand neutron scattering in the chemical sciences also involve scientists from other national laboratories and universities. Similarly, involvement in the establishment of the CNMS is increasing the number and scope of outside collaborations in the area of nanoscience.

This program has provided the foundations for important applications across DOE and at other Federal agencies, including the National Institutes of Health; the Environmental Protection Agency; the Departments of Agriculture, Treasury, Transportation, State, and Justice; and private industry. This research is distinguished by extensive collaborations between research areas within the chemical sciences program. In addition, the program is enhanced by extensive collaborations with other ORNL programs and with scientists at universities, at other national laboratories, and in the private sector. Each year, dozens of students at the undergraduate, graduate, and postdoctoral levels participate in our chemical sciences program.

Biological and Environmental Research

Strategic Objectives

These are dynamic times indeed for the research supported by the Office of Biological and Environmental Research (BER). Building on the DOE–National Institutes of Health (NIH) partnership that led to sequencing of the human genome, BER has laid out a scientifically exciting and ambitious plan to combine high-throughput proteomics technologies, next-generation imaging tools, and advanced computing to characterize and understand the functionality of proteins and protein complexes. Not only does this Genomes to Life (GTL) program, developed by BER in partnership with DOE's Office of Advanced Scientific Computing Research, have great scientific promise, it also has great potential for application in DOE's energy and environmental missions. The resulting knowledge and new tools will also provide valuable foundations for medical science. In climate research, advances in our understanding of basic physical and biological processes combined with the extraordinary improvements in computing technology offer the promise of greatly increasing the reliability of our climate models, applying them at regional scales, and understanding ecosystem dynamics from the molecular to the watershed scale. Similarly, the combination of new Genomes to Life (GTL) capabilities, the understanding of microbial ecology, and advances in subsurface science is creating innovative possibilities for controlling legacy contamination at DOE sites.

ORNL intends to play a major role in the realization of the GTL plan and in BER's programs in climate change and environmental remediation. We have established three strategic objectives:

1. We will help to achieve the major scientific goals of the GTL program, with particular emphasis on characterizing the structure and function of so-called "molecular machines," the protein complexes that carry out work inside living cells.
2. We will deliver new knowledge of the coupled climate-biosphere system, with emphasis on understanding ecosystem structure and function and biogeochemical cycles (carbon, water, energy, and nutrients), and will enhance tools for global and regional climate prediction and ecological modeling at the systems level.
3. We will support BER in translating the enhanced understanding of microbial biology and ecology and the technological advances that stem from the GTL program, coupled with new knowledge derived from fundamental research in earth and chemical sciences, to address issues in energy, environmental cleanup, strategies for mitigating the impact of climate change, and the development of new medical technologies.

Our scientific programs will be carried out through closely coupled experimental, theoretical, and computational research. To conduct this program, we will make extensive use of the new generation of major research facilities for protein characterization, along with the most powerful available supercomputers, and the field research facilities for ecology and earth processes operated by our Laboratory and by others. We will actively contribute to the development of new systems biology facilities and instrumentation and to the next generation of facilities for ecological and environmental remediation research.

Primary Roles in the Context of DOE Mission Objectives

The overall goals of the BER program are to advance environmental and biomedical knowledge that promotes national security through improved energy production, development, and use; international scientific leadership that underpins our nation's technological advances; and research that improves the quality of life for all Americans. To accomplish its goals, BER supports fundamental research, technology development, and leading-edge research facilities in the areas of life sciences (including genomics, proteomics, and radiation biology), climate change, environmental remediation, and medical applications and measurement sciences.

BER's goals in Life Sciences are to deliver fundamental knowledge of biological systems to address DOE needs in clean energy, carbon sequestration, and environmental cleanup and to understand the genetic basis of human susceptibility to energy-related pollutants. BER objectives supported by ORNL research are as follows:

- Understand the workings of biological systems: from multiprotein complexes to the regulatory networks that control them to the complex working of natural microbial communities;
- Develop novel technologies for high-throughput determination of protein and protein-complex structure and function;
- Characterize and exploit information contained in microbial genomes relevant to energy production, bioremediation, and global change;
- Identify and characterize the roles of genes and their regulatory networks in the human genome, using new technologies, comparative functional genomics, model systems, and information management;
- Understand and characterize the risks to human health from exposure to low doses of radiation.

We will support GTL with an integrated resource in systems biology that comprises microbial, plant, and mouse genomics; genome-scale proteomics and protein complex analysis (including mass spectrometry, advanced sample preparation and handling, cellular imaging, and other relevant analytical technologies); computational biology and bioinformatics; and structural molecular biology. This integrated resource will strongly enable the GTL focus on microbes with application to DOE's energy, climate, and environmental programs. It will also support application of GTL-derived knowledge and techniques in related research areas, including mammalian genomics and plant biology, that are outside the primary GTL focus. We will operate the Center for Structural Molecular Biology (CSMB) and associated upgrades to the High Flux Isotope Reactor (HFIR) to serve the structural biology community. We will also continue to conduct research on data analysis tools and information resources that provide information on the biological function of genes identified in high-throughput DNA sequencing projects.

Our research on the microbial genome will continue to emphasize organisms important to global change, carbon sequestration, energy production, marine biotechnology, and bioremediation. Our work on microbial community structure and function will provide the basis for understanding potential impacts of a changing climate on belowground ecosystems, from which it may be possible to promote increased sequestration of carbon below ground. We will also analyze the poplar genome sequence being completed by the Joint Genome Institute (JGI) for applications in carbon sequestration. Our research on microbial and plant systems will also lead to applied research and technology development on production and processing of biomass for fuel and power.

We will continue to characterize genes and their regulatory elements within the human genome, taking advantage of our unique capabilities in mouse mutagenesis and functional genomics. Our historical studies of low-level radiation effects on mammalian systems provide unique foundations for understanding the mechanisms of damage and repair in whole organisms in BER's Low Dose Radiation Research Program.

BER's goal in Medical Applications and Measurements Science is to deliver scientific knowledge and discoveries leading to innovative diagnostic and treatment technologies. BER's objectives supported by ORNL programs are as follows:

- Develop new radiotracers and radiopharmaceutical tools for detection and treatment of biochemical dysfunctions, including those which produce cancer, brain diseases, and mental disorders.
- Develop advanced imaging instrumentation for solving complex diagnostic problems in molecular nuclear medicine, such as imaging gene expression and monitoring gene therapy.
- Understand the functions of proteins and protein complexes by determining the three-dimensional structures of key proteins and the changes in protein structure related to interactions with other molecules, aided by new tools for visualization of proteins and protein complexes.

ORNL will explore the application of radioactively labeled monoclonal antibodies in medical diagnosis and therapy. We will continue to conduct research into new analytical instrumentation for complex environmental contamination using new types of biosensors. We also will conduct fundamental studies in biological and medical imaging and on biological and chemical sensors.

BER's goal in Climate Change Research is to improve the scientific basis for detecting, predicting, and assessing the effects of greenhouse gas and aerosol emissions on climate and the environment. BER objectives supported by ORNL research and data management are as follows:

- Understand factors affecting the Earth's radiant-energy balance.
- Develop and apply computational models for accurately predicting global and regional climate change induced by increasing atmospheric concentrations of aerosols and greenhouse gases.
- Quantify sources and sinks of energy-related greenhouse gases, especially carbon dioxide.
- Improve the scientific basis for assessing the potential consequences of human-induced climatic changes, including implications for ecological, social, and economic systems and the benefits and costs of alternative mitigation and adaptation options.

We will build upon existing strengths in biological and environmental science to advance a new scientific understanding—a new paradigm—that will focus on the fundamental translation of knowledge from biology to ecology (i.e., genomes to ecosystems), emphasizing acclimation and adaptation to changes in key environmental variables, and ecosystems as complex systems of multiple interacting species. An improved understanding of these relationships will strengthen our already strong leadership role in global change research, allowing ORNL to conceive, implement, and operate facilities for unprecedented long-term and large-scale ecological experiments. Such facilities will provide empirical data from which we will develop new theories and advanced formulations necessary for incorporating fundamental biological and ecological processes into next-generation biosphere models, with an initial focus on coupled carbon-climate models.

We will continue to house world-class data archives and information analysis centers, such as the Atmospheric Radiation Measurement (ARM) Archive and the Carbon Dioxide Information Analysis Center (CDIAC). These centers will facilitate analysis and model-data evaluations

Specific ORNL roles in BER subprograms	
Subprogram	ORNL Role
Life Sciences (SC-72)	Application of expertise in genetics, protein chemistry, molecular biology, computational biology and bioinformatics, biochemical engineering and bioprocessing, microbial and plant genomics, and analytical technologies such as mass spectroscopy, bioimaging, microarrays, and sensor application. Critical facilities: the CSMB and the Laboratory for Comparative and Functional Genomics, both designated DOE user facilities. Wide-ranging capabilities that support Genomes to Life, Health Effects Studies, the Low Dose Radiation Research Program, the Microbial Cell Program, and the Structural Biology Program. Heavy involvement in the GTL pilot projects, including leadership of the GTL Center for Molecular and Cellular Systems.
Medical Applications and Measurement Science (SC-73)	Expertise in biosensor development, high-throughput mass spectroscopic screening for genetic diseases, molecular and macro-scale bioimaging techniques, and studies of physiological phenomena using radioisotopes.
Climate Change Research (SC-74)	Expertise in carbon cycle and sequestration, ecosystem dynamics, microbial ecology and biogeochemistry, computational climate and environmental sciences, environmental data management sciences, and facility management. Critical centers and facilities: ARM Archive, CDIAC, Center for Computational Sciences, CSiTE, and several unique field research sites and facilities. Diverse capabilities that support Atmospheric Radiation Measurement, Carbon Sequestration Research, Climate Change Prediction Program, Biotechnology Investigations/ Ocean Margins Program, the Program for Ecosystem Research, and Terrestrial Carbon Processes Program.
Environmental Remediation Sciences (SC-75)	Expertise in biogeochemistry and geohydrology, microbial ecology and biotechnology, chemical separations, computational science, robotics, and facility management. Critical centers and facilities: Natural and Accelerated Bioremediation Research Field Research Center, Bioprocessing R&D Center, Center for Separations and Chemical Processing, Microarray Laboratory, soil blocks and lysimeters, and field research sites for subsurface transport in Walker Branch and Melton Branch watersheds. Extensive capabilities that support NABIR and the Environmental Management Science Program. Collaborations with the Environmental Molecular Science Laboratory at PNNL.

integrated with our modeling and experimental activities. In conjunction with Pacific Northwest National Laboratory (PNNL) and Argonne National Laboratory (ANL), we will continue to co-host the Consortium for Research to Enhance Carbon Sequestration in Terrestrial Ecosystems (CSiTE) and, in that capacity, provide the science-based understanding to support the development and assessment of terrestrial carbon sequestration strategies.

BER's goal in Environmental Remediation Sciences is to deliver scientific knowledge, technology, and enabling discoveries to understand contaminant behavior, expand available cleanup options, and understand the ecological impacts of remediation. BER objectives supported by ORNL research and facility management are as follows:

- Deliver science and technology to reduce costs, risks, and schedules for cleanup of DOE sites.
- Extend the frontiers of biological and chemical methods for remediation.
- Understand fundamental processes of fate and transport in the subsurface.
- Develop molecular tools for studying environmental processes.
- Advance the understanding of ecological impacts of remediation activities.

ORNL's research will support the cleanup of contaminated areas, develop new methods for treating current and future complex wastes, and provide a scientific basis for long-term stewardship. We will make critical contributions to the National and Accelerated Bioremediation Research Program (NABIR), providing special leadership in microbiology applied in the field. We will continue to operate the NABIR Field Research Center (FRC), a facility used for research supporting NABIR, the Environmental Management Science Program (EMSP), and other areas to advance field-scale subsurface science and for developing and testing bioremediation methods in subsurface environments. We will advance the development and use of microarrays for understanding microbial community structure and function. We will also support the EMSP by performing research in several disciplines, with special emphasis on contaminant fate and transport, robotics, sensors, and chemical sciences (including computational chemistry) relevant to complex wastes.

Objectives and Strategies

Objective 1: *Become a leading center and vital resource for understanding complex biological systems, from the molecular level to the level of the organism, as well as the interactions of organisms with their environment.*

Strategy

- See Complex Biological Systems Initiative.

Objective 2: *Develop a basic understanding of microbes and microbial systems, and their molecular machines and controls in their native environments (also see Complex Biological Systems Initiative).*

Strategy

- Improve tools and techniques for complex isolation, mass spectrometry, and computational analysis of protein complexes to achieve high-throughput characterization of structure and function, including analysis of complex variants generated under a variety of environmental conditions.
- Develop new tools and approaches for bio-imaging cellular processes.
- Develop new schemas for bioinformatics tools to capture, manage, and analyze the enormous amounts of data generated in the study of proteins, protein complexes, and their regulatory networks.
- Develop an understanding of microbial community structure and function through the characterization of regulatory networks in microorganisms using microarray technology and new models of stress response.
- Expand the CSMB via new facilities for protein deuteration and for biological small-angle neutron scattering at the HFIR to provide comprehensive information on the structure of biomolecular complexes.
- Advance the understanding of protein interactions at the molecular level and apply the resulting knowledge and technology to support DOE, National Institutes of Health (NIH), and

Recent Accomplishments

Life and Medical Sciences

- Vascular brachytherapy procedure developed by the ORNL Nuclear Medicine Program now in clinical use—2001. Uses beta radiation to keep arteries from re-narrowing following angioplasty and was pioneered by cardiologists at the University of Tennessee Heart, Lung, Vascular Institute, working with ORNL staff.
- Developed biosensors based on microcantilever technology and self-assembled monolayers of single-stranded DNA sensitive enough to detect a single-base pairing difference in DNA hybridization, affording the possibility of high-throughput, low-cost genomic and proteomic analysis, including real-time, portable, disposable sensors for biomedical applications—2002.
- Developed an integrated platform for detection of DNA sequence variants—2003. This highly versatile platform performs temperature-gradient capillary electrophoresis (TGCE), permitting fast, cost-effective detection of high-throughput mutation/single-nucleotide polymorphisms in genomic DNA sequences.
- Completed the CMMB—2003. This is a unique, high-throughput resource for functional genomics research; one of the first applications will be in functional annotation of genes on the mouse counterparts of the three DOE-sequenced human chromosomes.
- Demonstrated the importance of mouse mutants as unique models for exploring the roles of human genes through studies of ENU-induced mutations in genes on mouse chromosome 7—2003, locating a gene responsible for skull and spinal defects.
- Demonstrated that alterations in the Picalm gene, which encodes the clathrin-assembly protein, cause abnormal blood cell development and iron transport and other defects with human counterparts.
- Developed functional gene arrays, community genome arrays, and oligonucleotide arrays for analyzing microbial communities in complex environmental systems that allow insights into nitrogen and carbon cycling, as well as contaminant degradation, in research on bioremediation, global change, and carbon sequestration—2003.

Climate Change Research

- Showed that changes in eastern deciduous forests will play an important role in the cycling of carbon through the biosphere
  - Synthesis of results from the TDE shows that growth of mature trees is more resistant to changes in rainfall inputs and drought stress than predicted by existing ecosystem models—2003.
  - Results from the FACE facility show that an established deciduous forest stand absorbs more carbon from an atmosphere enriched with CO_2.
- Successfully tested an injector system for CO_2 sequestration in oceans, in collaboration with the Monterey Bay Aquarium Research Institute—2002.
- Assembled the most complete genetic map ever for a forest tree species (*Populus*) and applied it to identify specific regions of the genome responsible for aboveground and belowground carbon allocation/chemistry—2002.

Environmental Remediation Sciences

- Demonstrated the effectiveness of novel anion exchange resin and regeneration technologies in remediation of groundwater contaminated with perchlorate.
- Significantly improved a thermochemical model of the borosilicate glass system for sequestering nuclear waste by inclusion of chromia—2003.
- Achieved femtogram mass detection with cantilever oscillators—2002. Opens door to detection of atmospheric contaminants present in trace amounts as small particles or molecules of chemical contaminants, DNA, proteins, and even cells.

the Department of Homeland Security (DHS) missions related to human susceptibility, biotechnology, and medical technology.

Objective 3: *Develop the scientific and technological basis to measure and model ecosystem dynamics from the molecular to the ecosystem scale under changing climate conditions so that changes in ecosystem structure and function (cycling of carbon, water, energy, and nutrients; productivity; persistence of species;*

and maintenance of diversity) can be detected and strategies for adaptation, mitigation, or restoration can be supported.

Strategy

- Apply emerging tools in genomics and computational ecology to (1) discover indicators of ecosystem responses to climate change that span molecular to regional scales and (2) facilitate improved understanding of genetic, biochemical, and physiological processes responsible for key biological and ecological phenomena and that support the development of mechanistic models (see Complex Biological Systems Initiative).
- Improve representation of biological-ecological processes operating on timescales of decades in ecosystem and regional-to-global biosphere models (e.g., adaptation, response, and recovery from both natural and anthropogenic disturbance).
- Focus our science programs on the generation of critical data and improvements in process-based models that address terrestrial carbon cycling and ecosystem dynamics at large spatial scales. We will, where appropriate, explore the development of unique ecosystem and carbon cycle experimental facilities to maximize scientific disovery.
- Apply our strengths in data management and in computational climate science to support key DOE objectives for climate prediction, the North American Carbon Program, and ecosystem dynamics.

New perchlorate treatment and destruction technology recently developed at ORNL is being demonstrated at Edwards Air Force Base in California. Releases of perchlorate have been reported in 21 states.

Objective 4: *Operate the NABIR FRC with distinction for enabling scientific advances in bioremediation.*

Strategy

- Continue our focus on customer needs and support the requirements of individual researchers and collaborative teams.
- Support DOE's efforts to form a second FRC with our lessons learned and teaming so as to optimize DOE resources.

Objective 5: *Focus our capabilities to support BER in fate and transport science, waste treatment and processing, and long-term stewardship science.*

Strategy

- Maintain core research capability that advances the science and is competitive in NABIR and EMSP opportunities.

- Work with DOE cleanup stakeholders to transfer new science and technology to address local needs.
- Provide scientifically defensible simulation models to predict fate and transport of subsurface contaminants.
- Develop science and technology for long-term stewardship of lands with residual contamination.

Objective 6: *Understand the functionality of each gene in human chromosomes 5, 16, and 19, focused on a whole-organism level using the mouse as the model organism.*

Strategy

- Methodically induce point mutations in the homologous mouse chromosomes of the human chromosomes of interest, looking for lethality and for variants in phenotype expression in physiological, anatomical, or behavioral characteristics.
- Study the role of individual genetic variation in response to exposure to chemical and physical agents that affect the functionality of organisms.
- Using tissues from our Cryopreserved Mutant Mouse Bank (CMMB), identify point mutations in any DNA sequence (coding and regulatory) of interest, re-derive a mouse line with that tissue type, and study the consequences of that mutation at the organism level.

Researcher collects soil solution samples on the dry plot of the Throughfall Displacement Experiment (TDE) for determination of soluble plant nutrients.

Capabilities

The ORNL BER Program draws on distinguishing capabilities in biological and environmental research, with a focus on genetics and molecular biology, ecological and environmental systems, and environmental quality. These capabilities are supported by unique neutron science facilities (HFIR and the Spallation Neutron Source, now under construction) and extensive computational sciences resources. Environmental quality research is also supported by diverse chemical and analytical sciences capabilities and bioprocessing, hot cell, robotics, and environmental field research facilities. The breadth of these capabilities derives from ORNL's role as a multiprogram laboratory.

Key resources for ecosystem science include a variety of large-scale field research resources, located within the Oak Ridge National Environmental Research Park. These facilities, including the Free Air CO_2 Enrichment Experiment (FACE), the Throughfall Displacement Experiment (TDE), the Walker Branch and Melton Branch watersheds, and the NABIR FRC, are available to outside researchers.

The new Laboratory for Comparative and Functional Genomics, which will house the MGRF, and the CMMB represent an unparalleled resource for research on mammalian (mouse) genetics and

genomics. These resources, along with other user facilities such as the CSMB and the Bioprocessing R&D Center, provide state-of-the-art capabilities and equipment to biological researchers at ORNL and elsewhere.

Operational and Support Needs

Our ecological research facilities (e.g., FACE, NABIR FRC, data archival systems, etc.) require a transition to include operational support funds so that we may best serve the scientific community. Funding is required each year to support upgrading our capital equipment. Specific areas of need include genomic, field sampling, and analytical equipment.

Key Partnerships

Life and Medical Sciences—One key partner is the JGI, which provides the genomic sequences of microorganisms for computational annotation of genes performed by ORNL. In addition, ORNL has established an extensive network of partnerships for its current activities in the GTL program, including substantive involvement in the Shewanella Federation (see the Complex Biological Systems Initiative).

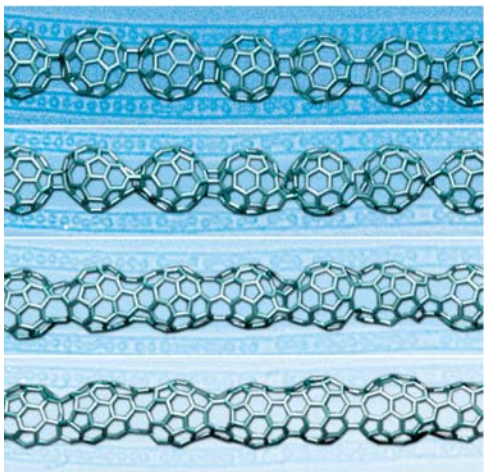
Climate Change Research—Our partnerships are many and focus on users of our field research facilities, data requesters (ARM Archive, CDIAC), and research partners: universities, national laboratories, and staff from other federal agencies, including the National Oceanic and Atmospheric Administration (NOAA) and the National Aeronautics and Space Administration (NASA). The Consortium for Research to Enhance Carbon Sequestration in Terrestrial Ecosystems includes PNNL and ANL, universities (Colorado State, Cornell, North Carolina State, Ohio State, Texas A&M, Virginia Tech, and Washington), the Joanneum Institute for Energy Research in Austria, and several USDA facilities. We are also engaged in the International Poplar Genome Consortium, which includes the JGI, the University of Washington, Genome Canada, and the Swedish University of Agricultural Sciences.

Environmental Remediation Sciences—Our work for EMSP and NABIR science heavily involves researchers from a diverse group of universities and other national laboratories, with a particular emphasis on users of our unique field research facilities (e.g., NABIR FRC).

Advanced Scientific Computing

Strategic Objectives

The use of computational tools has become vital to science and engineering and education in a multitude of national priorities such as anti-terrorism research, networking and information technology, nanotechnology, biotechnology, and climate change. The last three decades of sustained progress in computing technology, coupled with numerous breakthroughs in mathematical methods and computer science, have resulted in newer, more powerful tools for scientific research. These tools have brought new insights into complex systems beyond the reach of our most powerful experimental capabilities and sophisticated theories. Through modeling and simulation we are able to probe the interior of stars and discover how proteins work inside living cells. Indeed, computational science is now central to progress at the frontiers of nearly every scientific discipline and to our most challenging feats of engineering.



Sequence of tight-binding molecular dynamics simulation of fullerene coalescence inside a (10,10) nanotube. The simulation starts with ten buckyball molecules placed inside a single-wall nanotube. From top to bottom, the temperature increases from 1800 to 3600 K.

ORNL, together with our laboratory, university, and industrial partners, believes that it is critical for the future of high-end computing in the United States to bring into existence a new class of computational capability that is optimal for science. In recent years, scientific computing has become increasingly dependent on hardware that is designed and optimized for commercial application. Science in this country has greatly benefited from the improvements in computers derived from advances in microprocessors following Moore's Law, and a strategy of relying on machines optimized primarily for business applications. However within the last several years, in part because of the challenge presented by the appearance of the Japanese Earth Simulator, we have seen an increasing "divergence" of the needs of scientific applications and the platforms provided by vendors driven by the commercial market.

ORNL intends to support DOE by developing and deploying leading-edge computing capability and conducting state-of-the-art research and development in computer and computational sciences. In consultation with the DOE-SC Office of Advanced Scientific Computing Research (ASCR) and our collaborators, we have established three strategic objectives:

- Develop high-end computing capabilities that enable DOE and the nation to reassert U.S. leadership in computing and computational sciences. We will support the ASCR in its mission to deploy a next-generation, leadership-class supercomputing system for scientific applications.
- Develop petascale computing and simulation science capabilities that will enable DOE to develop innovative and revolutionary computational science skills to advance major national science and technology initiatives.

- Advance application of computational sciences in systems biology and biomedical engineering, materials science (nanoscience in particular), national security, climate sciences, and fusion sciences to solve the most critical problems. We will enable scientific discovery through advances in computational modeling and simulation by providing the models, tools, and computing infrastructure necessary to fully exploit those advances.

Primary Roles in the Context of DOE Mission Objectives

The DOE-SC Office of Advanced Scientific Computing Research (ASCR) is aimed at delivering forefront computational and networking capabilities to scientists nationwide to enable the extension of scientific frontiers in the physical, chemical, and biological sciences. ASCR mission is to discover, develop, and deploy the computational and networking tools that enable scientific researchers to analyze, model, simulate, and predict complex physical, chemical, and biological phenomena important to DOE.

DOE's ASCR objectives are to

- extend the frontiers of scientific simulation by creating computational models that fully exploit the power of advanced architecture computers;
- bring dramatically enhanced computing power to critical scientific challenges by encouraging the development and supporting the evaluation and application of computing architectures tailed to major scientific applications;
- advance scientific simulation by developing advanced computer science and mathematical tools and methods that enable simulation of complex systems on advanced architecture supercomputers; and
- provide computing resources, network infrastructure, and tools to enable computational science and scientific collaboration.

ORNL is actively engaged in supporting DOE in each of these missions.

ORNL will procure, evaluate, expand, and more rapidly bring to maturity High-End Computing (HEC) systems that have the potential to match or exceed the performance objectives of the DOE science missions and programmatic goals. In close collaboration with Cray, Inc., ORNL will strive to reassert U.S. leadership in high-performance computing for science in strategic areas important to DOE and the nation and will greatly enhance high-end computing in the United States. The Cray X1 and future generations of this product line promise to substantially increase the fraction of peak performance realized by many of the DOE Office of Science research applications.

Computational Sciences Building at the Oak Ridge National Laboratory.

ORNL's Center for Computational Sciences (CCS) will evaluate the processors, memory, and scalability of the architecture and software environment of the Cray X1 system to determine its effectiveness for the solution of the most challenging scientific problems. The Cray X1 offers vector processing and massively parallel processing capabilities in a single architecture and is specifically designed for scientific applications. Our evaluation approach will focus on scientific applications and the

computational needs of the science and engineering research communities. CCS will support "capability computing" in four strategic grand challenge research areas, as well as serve as a test bed to develop software and techniques needed to support "capability computing." The center will take full advantage of new high-speed networks and computer center facilities at ORNL, and its infrastructure will play an especially key role in moving the initiative forward. Finally, CCS will support computational science education, initially at the undergraduate and post-graduate level.

Part of the 40,000-square foot computer room in the new Computer Sciences Building.

Reasserting U.S. scientific leadership requires securing and evaluating multi-teraflop computational platforms and infrastructures coupled with an increase of expertise in modeling, simulation, and numerical methods for future architectures to take full advantage of increased capabilities. ORNL will work closely with other national laboratories to articulate the requirements to develop these future U.S. high-end, leadership-class computing capabilities.

The Office of Advanced Scientific Computing Research is leading a major DOE effort to advance the state of the art in computational modeling and enabling tools under the Scientific Discovery through Advanced Computing (SciDAC) program. The Center for Computational Sciences has a long history of accomplishments in scientific computing, has often served as the proving ground for many new computer technologies, and is a principal resource for SciDAC. Multidisciplinary, multi-institutional teams under SciDAC bring their collective experience and expertise to bear to realize the promise of terascale computers for its basic science programs. SciDAC focus areas include scientific challenge codes, computing systems and mathematical software, collaboratory software infrastructure, scientific computing hardware infrastructure, and scientific computing software infrastructure.

Profound implications for the tools and methods projects of SciDAC Integrated Software Infrastructure Centers will also result from the Cray X1 evaluation process, since vector architectures have been mostly neglected for the past decade in the United States. Without representative hardware, most computer science research and tool development has targeted commodity scalar processors and clusters. Methods research has pushed the scalability issues toward massive, distributed-memory configurations. While much of the research will be relevant and applicable to a Cray X1 with thousands of processors, the richness of the Cray software environment and high-bandwidth interconnect will shift the balance. The evaluation will give important information to tool designers and algorithm researchers about the relevance of current design and implementations.

Objectives and Strategies

Objective 1: *Assist DOE and the nation in revitalizing U.S. leadership in high-end computing and computational sciences.*

Strategy

- Participate in the interagency R&D roadmapping for high-end computing core technologies to develop a federal high-end computing, capacity, and accessibility improvement plan.

- Work with DOE laboratories and Office of Science leadership to articulate the requirements.
- Work with U.S. industry to develop high-end computing capability.
- Develop a sustainable partnership with partner universities in high-end computing.

Objective 2: *Lead the nation in developing and deploying high-end computing platform and infrastructure for science and engineering.*

Strategy

- Deploy a national capability, at the highest level of computing power that the industry and the research community can support with both efficient software and hardware, in the new world-class computing facility.
- Work with other DOE laboratories, academia, and industry to develop next-generation architectures suitable for science and engineering.
- Engage in significant development partnerships with U.S. vendors to bring new architectures into existence in a form, at a scale, and on a schedule that the scientific community can exploit successfully. Three such partnerships have already been established with IBM, Cray, and SGI.
- Leverage the new Defense Advanced Research Projects Agency (DARPA) High Productivity Computing Systems program and the architectures developed by the participants Cray, HP, IBM, SGI, and SUN.

Recent Accomplishments

- Received first cabinet of Cray X1 32 processor in 2002. The system will be expanded to a 256 processor system in 2003.
- Established a new partnership with SGI to build the world's largest shared memory machine for data-intensive applications such as computational biology.
- Established OC192 network connectivity: 10-Gbit/s network connection from ORNL through Chattanooga to the Atlanta. Using GigaPOP dramatically enhances communications performance between the university research community and ORNL.
- Completed first fully coupled climate simulation using T85 CAM; also POP climate code running on 16 processors achieved 35.3 simulation years per day—the fastest on any U.S. computer.
- Expanding Terascale Supernova Initiative: achieved 2- and 3-D hydrodynamics model runs uncovering instability in stellar core shock wave.
- Completed design of quasi-poloidal stellarator experiment using simulations.
- Optimized fusion simulator code TORIC for high-performance computing on ORNL's Cheetah at considerable timesaving.

Objective 3: *Enhance the accessibility of high-performance computing power, both within ORNL and for external partners.*

Strategy

- Provide sustained, high-bandwidth access to the highest possible performance computers for the most demanding applications at the scientific frontiers.
- Upgrade the network and data management infrastructure supporting these resources so as to enable computational scientists to manage the extraordinarily large volumes of data often generated by large-scale scientific computing and modern experiment.
- Create supporting resources, grid nodes, and tools that enable teams of scientists to collaborate effectively at a distance.

Objective 4: *Enhance university partnership and research in computational sciences.*

Strategy

- Attract key scientific leadership through joint faculty and distinguished scientist hires.
- Expand computing and computational sciences collaboration with the University of Tennessee (UT) and other universities through the Joint Institute for Computational Science (JICS).

Objective 5: *Advance application of computational sciences in advanced materials, climate sciences, systems biology, and fusion energy sciences.*

Strategy

- Operate CCS with a principal focus on computational biology, climate, fusion, and materials applications.
- Create, in partnerships across the Office of Science, new generations of models for fusion science, biology, nanoscience, physics, chemistry, climate, and related fields that provide high-fidelity descriptions of the underlying science.
- Incorporate the new models into scientific simulation software that obtains substantially greater performance from terascale supercomputers than currently achieved.
- Build on the successes of the SciDAC program.

Capabilities

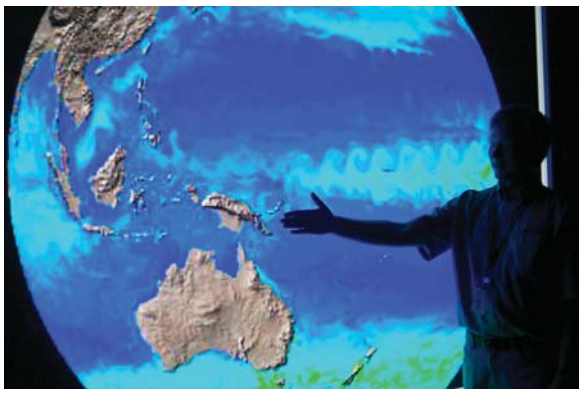
ORNL operates CCS, a DOE National User Facility, providing dedicated, unique computer facilities and user support for climate research, fusion, astrophysics, biology, and materials. The newly constructed state-of-the art facility has a 40,000-ft^2 computer center with a 36-in. raised floor, 18 ft deck to deck, and 12 MW of power with planned expandability. The 170,000-ft^2 Computational Sciences Building has office space for 400 staff, classroom and training areas for users, a high-ceiling area for state-of-the-art visualization, and separate lab areas for computer science and network research.

The CCS houses a 3.2-teraops Cray X1 "Phoenix" for early evaluation. Phoenix is a shared-memory vector system of 256 processors with 8 liquid-cooled cabinets, each with 128-GB memory, 8-TB disk, 1-TB shared memory, and 32 TB of disk space.

The CCS "Cheetah" is a 4.5-teraops IBM SP, an SMP cluster with 27 nodes, each with 32 IBM Power4 (5.6-Gflops) processors, 1-TB memory, and 24 TB local storage.

"Eagle" is a 1-teraops IBM SP, an SMP cluster with 184 nodes, each with 4 IBM Power3 II (1.5-Gflops) processors, 1086-Gflop/s of theoretical speed, 372 GB memory, and 9.2-TB local storage. The production system is dedicated to computational science research in computational materials, climate, biology, and nanoscience and engineering.

The High-Performance Storage System (HPSS) was developed by a consortium of DOE national laboratories and IBM. The DOE participants are ORNL, Sandia, Lawrence Berkeley, Los Alamos, and Lawrence Livermore national laboratories. ORNL's production HPSS installation now stores more than 70 terabytes.



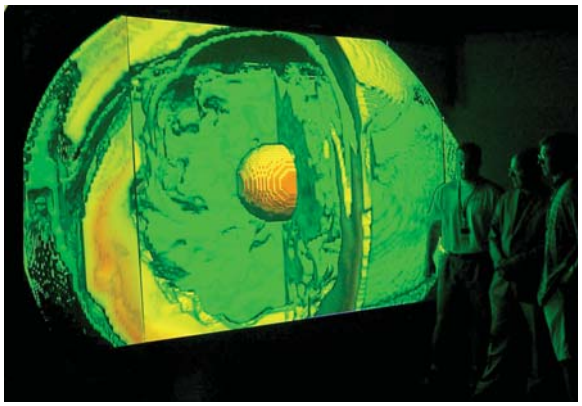
Ocean biochemistry simulation.

Operational and Support Needs

To achieve DOE's ambitious long-term objectives, we must collectively address the realities of leadership in the twenty-first century. We recognize several operational and support needs that would

accelerate progress in supporting DOE's ASCR mission. These needs are to

- recruit, hire, and retain world-class researchers in computing and computational sciences;
- fully utilize JICS to establish key collaborations and partnerships; and
- provide enabling Information Technology (IT) infrastructure and services, including IT support for facilities modernization.



Simulation results of core collapse supernovae mechanisms.

Key Partnerships

The Office of Advanced Scientific Computing Research supports ORNL efforts to enhance university and industrial partnerships and to strengthen our role in the nation's research enterprise by increasing the quality and impact of our user facilities and science and technology programs.

Many of ORNL's major partnerships have been developed through years of collaborative efforts such as SciDAC program and the CCS. Currently, ORNL is working with more than 13 other laboratories and 50 universities on collaborative efforts to advance and optimize high-end computing capabilities.

ORNL is also partnering with the UT-Battelle core universities and other regional and national universities to advance collaborative research projects and develop joint proposals. These partnerships are permitting ORNL to expand its expertise by developing a unique and diversified workforce. Central to ORNL's expanding relationships with universities, JICS with UT provides the mechanism for visitors, guests, and postdocs, as well as students, to participate in joint collaborative projects in computational sciences spanning computational biology, computational chemistry, computational materials science, fusion, and astrophysics.

Outreach through the Research Alliance for Minorities program continues to identify students and faculty members in science, mathematics, engineering, and technology disciplines for summer internships and collaborative research. The program supports of the long-term goal of increasing the number of underrepresented individuals with advanced degrees in the workforce and to expand research and educational relationships with historically black colleges and universities and other minority educational institutions.

ORNL is also strongly partnered with various computer vendors. Within the context of developing advance high-performance computers for the next century, ORNL has established partnerships with Cray, HP, IBM, and SGI for high-end computing for science and engineering, next-generation architectures and platforms, specialized applications thrusts, and high-end visualization. ORNL's advanced high-speed networks to link collaborative research partners and to enable massive amounts of data transfer benefits from a strong collaboration with Qwest.

Nuclear Physics

Strategic Objectives

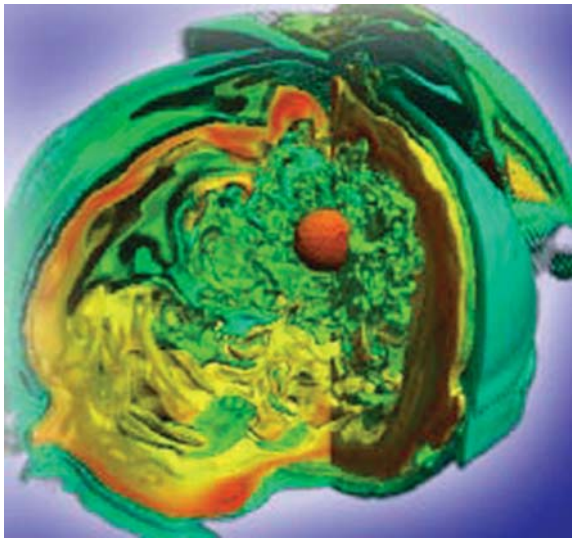
The nuclear physics community is making new exciting discoveries in the fundamental physics of nucleons and the behavior of nuclei under extreme conditions and is shedding new light on the evolution of our universe and the behavior of stars. The most recent Long-Range Plan established by the DOE/National Science Foundation (NSF) Nuclear Science Advisory Committee (NSAC) has proposed a bold and comprehensive set of initiatives to explore these rapidly developing areas of physics and to provide the major scientific instruments and theoretical tools needed to conduct these investigations.

ORNL intends to play a major role in the realization of the NSAC Long-Range Plan. In consultation with the Office of Science and our collaborators, we have established three strategic objectives for our nuclear physics program.

1. We will upgrade and operate the Holifield Radioactive Ion Beam Facility (HRIBF) as a nuclear physics user facility, supporting an international community of users in a broad range of nuclear physics studies and enhancing the technical basis for the proposed Rare Isotope Accelerator (RIA). We propose to increase current beam intensities by 1–2 orders of magnitude, develop a range of light- and intermediate-mass beams, and provide beams on both the proton-rich and neutron-rich sides of the region of stable nuclei.

2. We will deliver new understanding of the properties and behavior of neutrons, nuclei, and nuclear reactions at extremes of spin and isospin and of excitation. Our work will result in improved knowledge of properties and decay patterns at the limits of stability, understanding of the conjectured phase transition from nucleons into constituent quarks and gluons, and tests of the Standard Model predictions of neutron properties and decay.

3. We will develop new knowledge concerning the reactions that power stars and the stellar mechanisms resulting in gamma-ray bursts; novae; and, particularly, supernovae. This work will result in improved understanding of the synthesis of elements in stars and the explosive mechanisms whereby these elements are distributed in the galaxy and are made available for solar system and planetary formation.



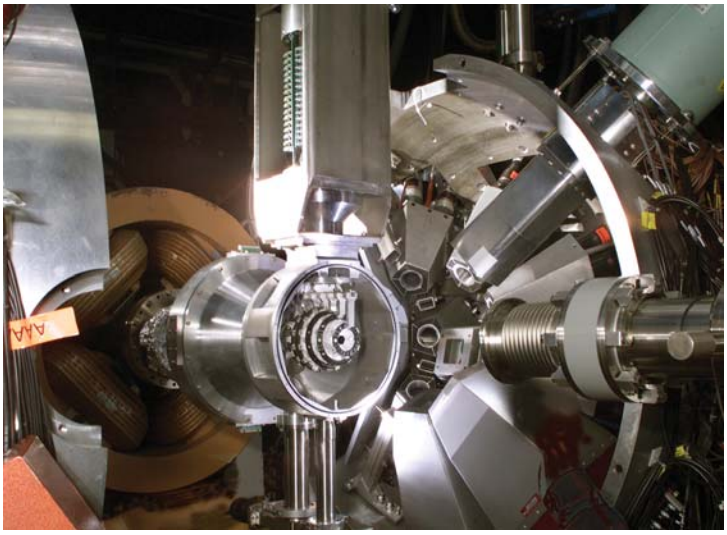
Supernova model visualization from the SciDAC effort showing polarization of radiation from the supernova.

Our scientific programs will be carried out through closely coupled experimental, theoretical, and computational research. We will make extensive use of the current generation of major nuclear physics research facilities, along with the most powerful available supercomputers, and actively contribute to

the design of facility upgrades and new facilities. Our programs are structured to encourage university partnerships and extensive student participation.

Primary Roles in the Context of DOE Mission Objectives

DOE's Nuclear Physics program addresses low- and intermediate-energy nuclear physics, heavy-ion physics, nuclear theory, nuclear data evaluation, advanced scientific computing for nuclear physics, and tests of symmetries and quantum field theories of subatomic matter. With the exception of the intermediate-energy area, ORNL has ongoing efforts in all of these fields. The Long-Range Plan lists eight initiatives, and ORNL has present and planned roles in support of most of these.



Recoil Mass Spectrometer (RMS) at HRIBF is used to study nuclear structures and the mass of reaction nuclei. Shown is the target end.

An overarching goal in the Long-Range Plan is to improve operation of existing facilities and invest in theoretical research. ORNL operates the HRIBF as a national user facility for low-energy research in nuclear physics. A proposed set of upgrades to HRIBF will more than double the annual hours of beam operation and improve the number and intensity of beam species provided. ORNL also operates the Oak Ridge Electron Linear Accelerator (ORELA), the nation's only operating "white" neutron source. ORELA is used for measurements of astrophysical reactions and nuclear-level properties important both for nuclear physics and new reactor concepts. The Joint Institute for Heavy Ion Research, sponsored by ORNL, the University of Tennessee, and Vanderbilt University, provides summer schools and undergraduate and graduate residential programs for students learning to conduct independent research. ORNL plans significant new investments in both nuclear structure and supernova theory, with an associated new effort in the physics of the strong nuclear force.

In the area of low-energy nuclear physics, DOE programs concentrate on the structure of atomic nuclei: understanding the limits of nuclear existence; probing how extreme proton / neutron (Z / N) ratios affect nuclear properties; and measuring how nuclear properties change with variation in Z / N, excitation, and angular momentum. ORNL conducts an extensive basic research program, including experimental, theoretical, and data-evaluation components. We study properties of nuclei that are far from stability and / or are highly excited. The experimental, detection, and theoretical tools are important for the planned RIA. ORNL invests in ion-source technology and detector development related to RIA. HRIBF also helps develop the scientific manpower base for RIA. In addition, the Long-Range Plan calls for constructing a high-resolution gamma-ray tracking array, GRETA. This novel device could lead to improvement in resolving power for gamma-ray decays of high spin state by a factor of as much as 1000. ORNL serves on the national governing board for GRETA, leads the electronics effort, and contributes to the full range of software initiatives for this project.

An ongoing effort in nuclear data evaluations serves DOE objectives in low-energy physics in three areas: the structure of actinide nuclei, elucidation of high-spin-level schemes, and reaction cross sections for the relatively low-energy nuclear reactions that are typical of stellar burning.

Nuclear astrophysics is a growing area at ORNL. DOE objectives include determination of the origin of the elements and learning how stars and galaxies form and evolve. ORNL concentrates on research using HRIBF and studying supernovae. Further programs evaluate astrophysical data and measure neutron-induced reactions of astrophysical interest using ORELA. Planned upgrades to HRIBF will improve the number and intensity of beams used to study reactions of astrophysical importance. A new program of cross-section measurements using the neutrinos produced in the main production target at the Spallation Neutron Source (SNS) will provide first-ever data on the mechanism thought to blow apart supernovae and spread their freshly produced atomic nuclei throughout the galaxy.

We are exploring development of an advanced tracking device for gamma rays based on multi-Compton scatterings in silicon tracking detectors. Such a device would make an excellent space-based telescope for gamma rays emitted from novae and supernovae. The technology has terrestrial applications in medical physics and radiological surveying for homeland security purposes.

In heavy-ion physics, the DOE objective is to determine whether nuclear matter can undergo a phase transition to a state where the quarks and gluons are no longer confined to the interiors of, for example, protons and neutrons. The Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory was built to test this hypothesis and to determine if an equilibrated form of such matter, referred to as quark-gluon plasma, can be produced in the laboratory, and to study its properties. Since the inception of PHENIX, one of two large experiments installed at RHIC, ORNL has played an important role in its design, construction, and operation, as well as in analyzing data from its main devices for detection of gamma rays and muons, the primary particles used to probe the "deconfined" stage of the reactions created at RHIC. ORNL is also defining the follow-on experiments to study properties of this state, using an upgrade of the PHENIX detector at RHIC or at the Large Hadron Collider (LHC), under construction at the European Organisation for Nuclear Research (CERN).

ORNL contributes to four of the five major program areas supported by the DOE Nuclear Physics Program.

Program Area	ORNL Role
Heavy Ion Research (KB02)	Supports the RHIC PHENIX.
Theory and Data Work (KB03)	Conducts nuclear theory program and nuclear data program on actinides and astrophysics.
Low-Energy Research (KB04)	Operates HRIBF as user facility; performs low-energy research, nuclear astrophysics research, SNS and HFIR neutron physics work, and ORELA measurements.
SciDAC program (KA04)	Performs theoretical and computational work on physics of supernovae (administered by High Energy Physics but is a purely Nuclear Physics subject area at ORNL).

DOE's objectives in theoretical nuclear physics span all aspects and energy ranges of nuclear behavior. ORNL has active theoretical programs that investigate the structure of nuclei, the evolution of this structure as limits to nuclear stability are reached, reactions occurring in stars the structure of excited hadrons/nucleons, and signals for quark and gluon deconfinement at RHIC. The Long-Range Plan also addresses utilization of large-scale scientific computing. ORNL leads one of the two Scientific Discovery through Advanced Computing (SciDAC) efforts approved for nuclear physics, concentrating on a novel approach to modeling supernova explosions by theoretical and computational description of the physics at the subatomic level, which is key to these explosions.

DOE's objectives in the final major area discussed in the Long-Range Plan include the search for violations of basic symmetries of quantum field theories; the determination of the nature of fundamental particles such as neutrinos; and the search for extensions (or even replacements) to the Standard Model of strong, electromagnetic, and weak forces. The Long-Range Plan mentions construction of a major underground science laboratory for very low background experiments and construction of a cold neutron beamline at the SNS for fundamental neutron physics.

ORNL has joined a group proposing a long-term experiment for an underground facility. The experiment would search for a rare, as-yet-unseen decay of ^{76}Ge involving emission of two beta particles but no neutrinos. (A positive result would require revisions to the Standard Model.) To this effort, ORNL brings expertise in germanium chemistry, germanium detectors, electronics, and relevant data analysis techniques. A new ORNL effort has begun to test fundamental symmetries and properties of the neutron. Precise tests of basic decay rates and properties are conducted to test the limits of the current Standard Model of particle physics. The new work at ORNL will provide the most sensitive measurements possible in the world.

Objectives and Strategies

In order to support the NSAC Long-Range Plan and ORNL's roles noted above, we plan to concentrate on current areas of strength in low-energy and heavy-ion nuclear physics, strengthen the astrophysics area, and add a new program in neutron physics using the SNS. Related efforts are proposed at other facilities, such as the High Flux Isotope Reactor (HFIR), as part of the overall neutron physics program at the SNS. Listed are seven major areas of program development in support of DOE Nuclear Physics.

Objective 1: *Upgrade HRIBF to provide doubled beam hours, new beam species, and 10–100 times greater radioactive ion beam (RIB) intensities.*

Strategy

- Design and present to DOE a rational sequence of staged upgrades to the HRIBF complex. Include, in order, a high-power target lab, a new target ion source, a new driver accelerator, and an axial-injected ion source plus power supply upgrades for the Oak Ridge Isochronous Cyclotron (ORIC).
- Carry out construction and commissioning and operate the upgraded facility as part of HRIBF.
- If the timing of RIA permits, propose and build a booster accelerator for HRIBF.

Objective 2: *Construct/operate a cold neutron beamline at SNS for fundamental neutron physics.*

Strategy

- Engage community in evaluating the SNS solution.
- Organize scientific collaborations, design beamline and experiments, and obtain SNS approvals and include need in the NSAC Long Range Plan.

Objective 3: *Establish new nuclear theoretical efforts in nuclear structure, computational astrophysics, and strong interactions.*

Strategy

- Build university-based theory collaborations.
- Prepare proposals for new initiatives in nuclear structure theory and for a "co-laboratory" in supernovae theory.
- Respond to expected call for proposals after summer / fall 2003 NSAC theory review.

Objective 4: *Expand low-energy research program into expected centerpiece RIA physics areas in anticipation of RIA construction.*

Strategy

- Invest in research, detectors, and operational improvements for HRIBF.
- Perform targeted R&D in support of RIA design of ion sources and detectors.
- Actively participate in all RIA planning workshops to ensure a place for low-energy research group in RIA construction and science program.
- Take responsibility for design and construction of one or two experimental endstations at RIA.

Objective 5: *Perform definitive experiments at RHIC to search for quark-gluon plasma.*

Strategy

- Prepare long-term run plan for RHIC PHENIX detector.
- Carry out ORNL's responsibilities in the analysis of photon and muon-pair data.
- If quark-gluon plasma is found, design / propose / build / perform follow-up experiments to delineate properties at RHIC or at CERN LHC, as needs dictate.

Objective 6: *Establish new direction for the nuclear data program in astrophysics.*

Strategy

- Develop a scientific and programmatic case for such effort, emphasizing the major programmatic thrust on astrophysics expected at RIA.

Key Accomplishments

HRIBF operations have achieved over 1200 hours of RIBs and 2000 total hours of beam. RIBs delivered include brand-new isotopically pure beams of isotopes such as ^{17}F and ^{18}F for the astrophysics program and the long-sought ^{132}Sn (the heaviest doubly closed shell unstable nucleus known) for the nuclear structure program. The fluorine experiments resolved several puzzles about the nucleosynthesis cycle which produces carbon, nitrogen, and oxygen (the "CNO cycle") in stars such as our own sun.

The RHIC PHENIX program has seen evidence that the matter produced is highly opaque to penetrating particles that easily traverse normal nuclear matter. This is behavior suggested for the sought-after quark-gluon plasma state. The achievement depended, in a principal way, on the large photon spectrometer, which ORNL helped build at CERN in 1992–1994, brought to BNL in 1997, and instrumented for PHENIX.

Advances in supernova modeling can now predict the polarization of radiation emitted from supernovae, in accordance with observation. This is the first computational effort ever to achieve this and required detailed knowledge of the nuclear microphysics of supernovae.

Excitation studies of neutron-rich nuclei around the ^{132}Sn closed shell using reactions at sub-barrier energies have given first-ever information on the evolution of nuclear shell structure near a double-closed-shell nucleus that is well away from the region of stable nuclei.

- Create evaluation methods, reaction rate codes, and WWW / graphical interfaces for this work.
- Emphasize to university colleagues in the field and at national and international nuclear data conferences the need for and utility of the ORNL approach and evaluation methods.

Objective 7: *Establish neutrino cross-section program at SNS.*

Strategy

- Prepare theory-based arguments about the need for such cross sections to understand supernovae and their relevance to SciDAV and RIA efforts. Establish possible floor areas at SNS, and form an SNS-recognized team.
- Partner with the University of Tennessee Physics Department to establish detector concept and prototype.

Capabilities

ORNL has two major accelerator-based capabilities for DOE's Nuclear Physics program. One is the HRIBF complex, the only Isotope Separator On Line (ISOL) facility in the United States and the only one in the world with post-acceleration capability, thus allowing it to deliver precise, well-collimated beams of RIBs to targets for further experimentation. HRIBF is unique in its ability to produce both proton-rich and neutron-rich post-accelerated beams of RIBs for experiments. The other ORNL capability is the SNS complex, with its world-class beams of pulsed cold neutrons and source of moderate-energy neutrinos. A part of the neutron physics program can also be carried out at the cold source now being built for HFIR. Some facets of the nuclear astrophysics program can also benefit from use of the ORELA white neutron source. ORNL has extensive facilities for advanced computation using some of the fastest unclassified computers in the world. ORNL also has relevant expertise in detection devices, materials preparation and characterization, isotope separation, and custom analog and digital electronics design, all of which are brought to bear on current questions in the DOE Nuclear Physics Program.

Operational and Support Needs

Continued support for HRIBF operations and the 6000-area physical plant is needed for the low-energy program. Completion of the cold sources at SNS and HFIR is required for the success of the science program in fundamental neutron physics. Expansion of the program in criticality and reactor-related measurements at ORELA would ensure a stable funding base for that accelerator. Improvements in large-scale computational resources would benefit the entire theory program. The possible new cold source at HFIR would provide unmatched capabilities for ultra-cold neutron work. ORNL's world-class capabilities in the development of custom analog circuits and application-specific integrated circuits (ASICs) should be maintained to support the increasingly complex needs for subatomic particle detection.

Key Partnerships

Three significant partnerships are key to ORNL programs in nuclear physics. The first is the Joint Institute for Heavy Ion Physics, jointly administered by ORNL, UT, and Vanderbilt. This provides a venue for visitors, guests, and postdocs as well as a starting point for many productive collaborative efforts. The second is the PHENIX collaboration based at Brookhaven National Laboratory. ORNL is a charter member of this 450-physicist effort and has had a leadership role since its inception. The third is the user group for HRIBF, which is broadly based in the United States and abroad.

Fusion Energy

Strategic Objectives

Nuclear fusion is a key element of the nation's long-term energy strategy because of its potential advantages as an energy resource. The development of commercial fusion energy could enhance the nation's energy security, provide an environmentally acceptable alternative to fossil fuel combustion, and help ensure continued economic growth through reliable electricity supply.

The mission of DOE's Fusion Energy Sciences (FES) Program is to advance plasma science and fusion science and technology, building the knowledge base needed for an economically and environmentally attractive fusion energy source. The program supports research to understand the physics of plasmas; to identify and explore innovative and cost-effective development paths to fusion energy; and, as a partner in international efforts, to advance the science and technology of energy-producing plasmas.

ORNL conducts an extensive and well-integrated program of science, technology, and engineering that is aimed at developing the understanding required for an attractive fusion energy source. We intend to play a leading role in achieving the FES mission and have established the following objectives for our fusion energy program:

- Develop innovative plasma confinement configurations, advance the theory and modeling of plasma stability and collisional and turbulent transport, and develop radio-frequency (rf) heating to control advanced confinement regimes.
- Advance our understanding of plasma boundary physics, fueling and particle transport, confinement and stability, wave-plasma interactions, and concept innovations through basic research.
- Develop enabling technologies: (1) technologies for plasma heating and current drive and for fueling of plasmas to create, control, and understand high-temperature plasmas and (2) advanced design and chamber technologies to help identify and resolve fusion reactor issues (e.g., reliability, availability, and maintenance).
- Advance the materials science base to develop high-performance structural materials with attractive environmental and safety features.
- Investigate atomic, molecular, and surface interactions to develop basic knowledge and needed data for plasma science.

Primary Roles in the Context of DOE Mission Objectives

ORNL conducts cross-cutting research in science and technology in support of the Office of Fusion Energy Science's mission to "advance plasma science, fusion science, and fusion technology—the knowledge base needed for an economically and environmentally attractive fusion energy source." We apply ORNL's capabilities in plasma theory and modeling, experimental plasma physics, plasma technology, advanced materials, atomic physics, diagnostics, neutronics, engineering, and remote maintenance to develop and deploy new fusion concepts, with an emphasis on the needs of International Thermonuclear Experimental Reactor (ITER), the next major step for the development of fusion. We also pursue near-term applications of plasma science and technology in support of national goals, including isotopes production, high-temperature superconducting electric power

applications, and plasma propulsion systems. These efforts are closely aligned with the preparation plans at the Office of Fusion Energy Sciences (OFES) as informed by the recent Fusion Energy Sciences Advisory Committee report.

ORNL's primary roles in the context of the DOE OFES mission are as follows.

DOE-OFES Mission Objectives	ORNL Roles
1. Fundamental Understanding • Theory, modeling, and simulation • General plasma science	• Advance fundamental understanding of transport. • Develop predictive capability for plasma heating, flow, and current drive, and for plasma boundary physics. • Develop plasma modeling capability for advanced confinement concepts. • Investigate atomic and molecular phenomena, as well as surface interactions, to develop basic knowledge and needed database for plasma science. • Pursue near-term applications of plasma science and technology in support of national goals.
2. Configuration Optimization • Advanced tokamak and alternate confinement concept experiments • Enabling R&D	• Develop advanced tokamak scenarios in DIII-D. • Address burning plasma issues in DIII-D and Joint European Torus. • Develop computational tools for optimization of three-dimensional confinement systems. • Develop the compact stellarator concept. • Develop database for the spherical torus. • Develop and implement plasma fueling, pumping, and disruption mitigation technologies. • Develop and implement high-power radiofrequency (rf) and microwave heating and current drive technology.
3. Burning Plasma Experiment • ITER support	• Participate in the International Tokamak Physics Activity (ITPA). • Prepare diagnostics for tritium operation in JET and for ITER. • Develop disruption mitigation techniques for ITER. • Develop fueling and heating schemes for ITER .
4. Enabling Technologies and Fusion Materials • Fusion materials • Fusion technologies	• Establish materials science base for advanced materials for fusion. • Develop remote handling and metrology technologies. • Develop fusion nuclear database and computational tools.

Technologies developed in the fusion program are spun off to nonfusion areas and transferred to the private sector. Applications include such areas as plasma processing and propulsion, high-temperature superconducting power transmission systems, and power grid reliability.

Objectives and Strategies

Objective 1: *Advance the fundamental understanding of plasma science and develop an integrated simulation capability for fusion plasmas and reactors.*

Strategy

- Use ORNL's broadly based plasma theory program to (1) advance the fundamental understanding of transport; (2) develop a predictive capability for plasma heating, flow, and current drive, and plasma boundary physics; and (3) develop plasma modeling capability for advanced confinement concepts.
- Exploit the experience gained in the Scientific Discovery through Advanced Computing (SciDAC) project on numerical computation of wave-plasma interaction in multidimensional systems and terascale computing and the recent development of three-dimensional computational tools for stellarator physics to advance integrated predictive capabilities of fusion systems such as ITER, as well as existing and planned experimental devices.
- Secure a substantive role in related computational fusion science initiatives, such as the Fusion Simulation Project (FSP).
- Continue to meet the need for atomic collision and particle-surface interaction data while also advancing the underpinning atomic, molecular, and surface science required to provide this capability.
- Improve the understanding of particle interactions with plasma-facing components.
- Use novel theoretical and experimental techniques to study ion-atom and electron–molecular ion collisions that are important to modeling and diagnosing edge and divertor plasmas.

Recent Accomplishments

- In a multi-institutional SciDAC project led by ORNL, the first fully resolved two-dimensional (2-D) calculations of the conversion of fast rf waves to short-wavelength modes in plasma were obtained. This mechanism is important for driving the internal currents and flows required for maintaining and improving plasma confinement.
- A unique atomic-scale probe of material surfaces was demonstrated through the study of neutralization of ions backscattered from metals and insulators, elucidating the simplest prototypes of the complex cascades occurring in the ion-solid interactions of fusion plasma–wall collisions.
- In collaboration with Princeton Plasma Physics Laboratory (PPPL), ORNL has developed high harmonic fast wave heating and current drive for National Spherical Torus Experiment (NSTX), which is crucial for long-pulse, high-performance operation of the spherical torus concept.
- ORNL, in partnership with PPPL, developed two variants of a new innovative plasma confinement concept—the compact stellarator. The National Compactor Stellarator Experiment (NCSX) and Quasi-Polodial Stellarator (QPS) devices combine the best features of the tokamak with those of the other major confinement approach, the stellarator.
- ORNL staff, in collaboration with the DIII-D national team, developed novel operating scenarios for ITER through computer modeling and experimental verification.
- In collaboration with General Atomics, a new ITER-relevant plasma disruption mitigation technology has been demonstrated.
- In collaboration with PPPL, ORNL developed an ITER-relevant high-power prototype rf heating antenna for the JET tokamak in Europe.
- ORNL and its collaborators have developed an advanced silicon carbide (SiC) composite ceramic for fusion energy applications. Unlike commercially available SiC composites that become substantially weaker during neutron irradiation, the strength of the new formulation was shown to improve by 5 to 10% after irradiation at the High Flux Isotope Reactor.

Objective 2: *Establish the scientific basis for more attractive fusion systems by developing and investigating innovative magnetic confinement configurations.*

Strategy

- Develop Advanced Tokamak (AT) scenarios for ITER, primarily on the DIII-D facility at General Atomics.

- Assess the attractiveness of the Spherical Torus (ST) concept through continued collaboration on the National Spherical Torus Experiment (NSTX) at the Princeton Plasma Physics Laboratory (PPPL).
- Continue the development of the low-aspect-ratio Compact Stellarator, a concept that combines the best characteristics of the tokamak and the conventional stellarator, by partnering with PPPL to build the National Compact Stellarator Experiment (NCSX) at Princeton and by leading a collaboration with PPPL, the University of Tennessee, and other universities to design and build the very-low-aspect-ratio Quasi-Poloidal Stellarator (QPS) at ORNL.

High-power prototype (HPP) radio-frequency heating antenna for the JET tokamak. The JET HPP antenna is a prototype of the "ITER-like" JET-EP antenna, which addresses many technical challenges expected in ITER.

Objective 3: *Advance DOE's Burning Plasma Experiment initiative by providing expertise, R&D, and components during the construction phase of ITER.*

Strategy

- Exploit ORNL capabilities in plasma theory and experiments, plasma and fusion technologies, diagnostics, and engineering design and analysis to contribute to ITER in the areas of components and systems to be furnished by U.S.-specific tasks, physics and engineering design and analysis, R&D, fabrication and testing of components, and coordination with the United States and the other international participants / teams.
- Participate in the International Tokamak Physics Activity (ITPA)
- Participate in burning plasma experiments and prototype component tests and R&D (heating, fueling, diagnostics) on DIII-D, the Joint European Torus (JET), Tore Supra, and others.
- Develop an integrated modeling / simulation capability for burning plasma and reactor systems.
- Develop fueling, heating, and disruption mitigation systems for ITER.
- Prepare diagnostics for tritium operation in JET and for ITER.
- Participate in ITER design integration and assembly and development of fusion design codes and databases.

Objective 4: *Develop enabling technologies for DOE's fusion research facilities and establish the materials science basis for the fusion energy application.*

Strategy

- Continue to lead a research program to understand the factors limiting the operation of rf antennas on present-day devices and to develop improved rf systems for use on future machines, in partnership with DIII-D, NSTX, Alcator C-Mod, and several other facilities.
- Complete the testing of a high-power prototype of an advanced "ITER-like" rf antenna for the JET experiment.

- Continue the basic development of new techniques, the implementation of these techniques on existing fusion facilities, and conducting topical collaborations on fueling and heating on a broad range of domestic and international facilities.
- Develop and understand structural materials with attractive safety and environmental characteristics by continuing our two long-standing collaborations with the Japan Atomic Energy Research Institute and Japanese universities and leveraging DOE's substantial investment in materials modeling, nanotechnology, and research reactors (HFIR) to understand fundamental radiation effects phenomena in structural materials and to develop improved radiation-resistant materials. Continue to focus on advanced materials including reduced-activation ferritic/martensitic steels, nanocomposited oxide dispersion–strengthened steels, refractory alloys, and ceramic composites.

Capabilities

ORNL capabilities in support of the fusion program include theory, modeling, and simulation; experiments; fusion technology development; fusion materials; and atomic physics and diagnostics development.

Theoretical research on high-temperature plasmas uses state-of-the-art computational resources to address transport phenomena, magnetohydrodynamics behavior, rf heating and current drive, optimization of 3-D confinement systems, and plasma boundary effects. The experimental group conducts experiments on nearly all major fusion facilities, national and international. ORNL researchers develop rf heating and current drive technology and high-speed frozen pellet fueling technology. ORNL is a major contributor to the development of low-activation, radiation-resistant materials for fusion; to studies of atomic physics relevant to fusion; and to diagnostics development. The Controlled Fusion Atomic Data Center at ORNL compiles, evaluates, recommends, and disseminates atomic and molecular collision data relevant to fusion energy R&D. The Multicharged Ion Research Facility (MIRF), now undergoing a major upgrade sponsored by OFES and the Office of Basic Energy Sciences, supports exploratory studies of the interactions of ions and surfaces relevant to edge, divertor, and scrape-off plasmas of fusion devices.

Operational and Support Needs

ORNL's contribution to the DOE Fusion Energy Sciences Program depends on completion of three facility projects:

- Complete the Multipurpose High Bay Facility in the Melton Valley area.
- Complete the move of the ORNL Fusion Energy Division from the Y-12 National Nuclear Security Complex to the main ORNL campus.
- Complete the major upgrade of the Multicharged Ion Research Facility (MIRF).

Energy Efficiency and Renewable Energy

Strategic Objectives

The energy challenges facing the nation have never been greater. Our transportation sector is nearly 97% dependent on oil and more than 50% of the oil is being imported, much of it from the Middle East. The U.S. transmission system is congested, resulting in increased costs to consumers, risks of blackouts, and vulnerabilities to natural and terrorist threats. The nation's current fossil energy technologies threaten air quality (with significant health costs) and may be impacting the global climate (with potentially large economic and social costs). According to the *National Energy Policy* report (May 2001), these challenges spring from a fundamental imbalance between domestic energy supply and domestic energy demand.

Scientific and technological breakthroughs offer unprecedented opportunities to solve these challenges. Recognizing this potential, DOE's Office of Energy Efficiency and Renewable Energy (DOE/EE) harnesses the nation's technological know-how to promote energy conservation, repair and modernize the nation's energy infrastructure, and increase domestic energy supplies in ways that protect and improve the environment (DOE/EE's Strategic Plan, October 2002).

The mission of ORNL's Energy Efficiency and Renewable Energy (EERE) Program is to develop sustainable energy technologies that foster a cleaner environment, a stronger economy, and a more secure future for the nation. In consultation we have established five strategic objectives:

- For the Distributed Energy Resources (DER) Program, ORNL will deliver technological breakthroughs and systems optimization that will advance on-site energy resources, reduce peak demand for energy, and improve the efficiency with which energy is provided and distributed.
- For the FreedomCAR and Vehicle Technologies (FCVT) Program, ORNL will deliver technology breakthroughs that will increase the energy efficiency and reduce the environmental impact of the transportation sector.
- For the Hydrogen, Fuel Cells and Infrastructure Technologies Program, ORNL will develop materials and processes for fuel cell systems and for the practical generation, storage, and delivery of hydrogen as an energy carrier.
- For the Building Technologies, Industrial Technologies, and Federal Energy Management Programs, ORNL will deliver breakthrough technologies that will modernize energy efficiency in the nation's industries, homes, commercial buildings, and federal facilities.
- For the Biomass, Solar and Wind and Hydropower Programs, ORNL seeks to develop renewable energy technologies that can tap America's vast and diversified domestic renewable resource base.

The program employs an integrated approach to achieve these objectives by

- combining basic and applied research with technology development and demonstration activities;
- drawing on the expertise of multidisciplinary teams of world-class scientists and engineers capable of tackling large and complex problems;
- engaging a wide array of industrial, academic, and public-sector partners in the definition, execution, and assessment of its activities;

- utilizing state-of-the-art research equipment in six DOE/EE-sponsored national user facilities; and
- drawing on crosscutting laboratory expertise including materials, sensors and controls, power electronics, and advanced computing, with potential for significant breakthroughs across the entire EERE program.

In addition to conducting research for the DOE/EE Technology Development Programs, ORNL also assists the DOE/EE Business Administration Office in several areas of analysis, including program evaluation and benefits assessment, supply chain analysis, consumer valuation of technology attributes, transportation systems analysis, and analysis of biomass supply and demand.

The program's activities and approach respond to the goals outlined in the *National Energy Policy* report (May 2001), DOE/EE's *Strategic Plan* (October 2002), the *Energy Efficiency and Renewable Energy Strategic Program Review* (March 2002), and the *National Transmission Grid Study* (May 2002).

Distributed Energy Resources

Primary Roles in the Context of DOE Mission Objectives

ORNL's R&D for the Distributed Energy Resources (DER) Program focuses on improving technologies and systems for distributed energy resources.

Program Area	ORNL Roles
Distributed Energy Resources	• Improved distributed energy technologies (microturbines and industrial turbines, natural gas engines, and hybrid technologies) • Combined heat and power (CHP) • Optimized and integrated end-use generation and combined heat and power to achieve 60% energy efficiency at the appropriate levels of power quality and reliability

Objectives and Strategies

Through collaborative R&D, ORNL will deliver technological breakthroughs and systems optimization that will advance on-site energy resources, reduce peak demand for energy, and improve the efficiency with which energy is provided and distributed.

Objective 1: *Expand ORNL's capabilities in materials, emissions controls, power electronics, and modeling to enable the development of marketable distributed energy resources that are 25% more efficient than 2000 baseline technologies.*

Strategy

- Use results from LDRD-funded research as the basis for individual proposals to sponsors in DOE and elsewhere.

- Develop research partnerships with major U.S. stakeholders including the Tennessee Valley Authority, industry, universities, and other national laboratories such as the National Renewable Energy Laboratory (NREL).

Objective 2: *Establish new facilities at the Energy Reliability and Efficiency Laboratory (EREL) to advance DER research goals.*

Strategy

- Seek funding for equipment to enable systems integration and component research, including accelerated life cycle testing; emission and noise attenuation; and assessment of threshold levels of power interruption.

Key Accomplishments

- Tests have been completed on ceramic composite materials for combuster liners in high-temperature furnaces (Keiser rig) at ORNL. These tests helped Solar Turbines and United Technologies develop ceramic combuster liners that have now been tested for over 15,000 hours.
- ORNL developed a new cast stainless steel that improves high-temperature durability, performance, and reliability based on ORNL's unique engineered microstructure alloy development methodology.

Capabilities

The program utilizes a unique research facility, the Combined Cooling, Heating, and Power Integration Laboratory, that was specifically developed for the DER Program. This national user center assists industry in developing CHP package systems that are energy efficient and is used to assess system components to improve performance. It tests the ability of CHP systems to achieve resource efficiencies of 40–70% by focusing on the innovative integration of distributed generation, heat recovery, and thermally activated cooling and humidity control technologies into highly efficient CHP systems.

The program also draws from significant expertise and facilities from other parts of the Laboratory, including the High Temperature Materials Laboratory, which provides state-of-the-art materials characterization.

Operational and Support Needs

To be successful, support is needed in equipping the EREL for DER research, once construction of the new facility is completed at the end of FY 2006.

Key Partnerships

Partnerships have been established with U.S. manufacturers, energy service providers, national laboratories, universities, and utilities to advance technology, reduce development and operating costs, and maintain a competitive position with the most efficient and cleanest on-site generation systems. The DER Program involves numerous critical industrial partners including Solar Turbines, Capstone, Cummins, Caterpillar, Trane Corporation, Carrier, and General Electric, as well as the Electric Power Research Institute-Power Electronics Applications Center. In addition the DER Program and DOE's Federal Energy Management Program (FEMP) have forged a strong partnership for technology transfer and deployment through federal agency use of advanced DG/CHP in their own facilities. For example, the DER and FEMP teams at ORNL have been instrumental in motivating the first demonstrations of advanced packaged CHP systems, using a 5-MW industrial tubing prime mover at the Army's Fort Bragg in North Carolina and two 60-kW microturbines at the Floyd-Bennet Field site of the National Park Service in New York.

Transportation, Hydrogen and Fuel Cells

Primary Roles in the Context of DOE Mission Objectives

Program Area	ORNL Roles
FreedomCAR and Vehicle Technologies	• Advanced materials and processes for automotive and heavy-vehicle structural components and propulsion systems • Power electronics and electric machinery for hybrid electric and fuel cell vehicles • Advanced fuels, engines, and emission control systems for increased energy efficiency and reduced emissions
Hydrogen, Fuel Cells, and Infrastructure	• Fuel cell materials • Advanced processes and materials for hydrogen generation, delivery, and storage

Objectives and Strategies

Through collaborative R&D, ORNL will deliver technology breakthroughs that will increase the energy efficiency and reduce the environmental impact of the transportation sector, ultimately providing science and technology to enable a U.S. transportation system that does not depend on foreign sources for fuel. ORNL will develop materials and processes for fuel cell systems and for the practical generation, storage, and delivery of hydrogen as an energy carrier.

Objective 1: *Expand analytical and modeling and simulation capabilities that support the DOE FreedomCAR and Vehicle Technologies (FCVT) mission and goals for advanced materials.*

Strategy

- Complete Advanced Materials Characterization Laboratory and take delivery of aberration-corrected electron microscope.
- Use results from LDRD-funded simulation and modeling of advanced materials processing as the basis for research proposals to DOE FCVT.

Objective 2: *Establish new and expanded facilities for R&D on polymer composites.*

Strategy

- Integrate existing equipment into new 12,000-ft^2 composites laboratory located in new facilities under construction at ORNL main campus.
- Leverage existing partnerships, expertise, and intellectual property to expand the R&D program in materials processing and characterization, focusing on crashworthiness of composites, and carbon fiber manufacturing, forming, curing, and assembly, to support construction of additional laboratory facilities.
- Increase collaborations with University of Tennessee and other universities that have nationally and internationally recognized expertise in various aspects of composites research, development, and application.

Objective 3: *Establish facility to support expansion of the Fuels, Engines and Emissions Research Center to include R&D on hydrogen-fueled internal combustion engines and potentially other hydrogen-related research and development activities.*

Strategy

- Complete construction of an annex to the National Transportation Research Center as a leased, privately owned facility.
- Develop strategic partnerships with industrial leaders.
- Collaborate with industrial and private partners to obtain specialized equipment for the facility.

Objective 4: *Build a world-class hydrogen R&D program at ORNL. (See also the Science and Technology for a Hydrogen Economy Initiative.)*

Strategy

- Establish a Virtual Center for Hydrogen Storage in the area of chemical hydrides, with supporting roles in carbon materials and metal hydrides.
- Establish ORNL's inorganic membrane technology as the lead membrane for hydrogen purification.
- In collaboration with NREL, develop by 2010 an economic means of producing hydrogen in large quantities from biomass.

Key Accomplishments

- The Physical and Virtual Test Machine for Automotive Crashworthiness (TMAC) was installed in November 2002. The result of a collaborative effort involving ORNL, the Automotive Composites Consortium, and MTS Systems, Inc., the TMAC is a custom experimental apparatus that provides data to enable accurate crashworthiness test modeling of vehicle components made from lightweight metals and composites.
- ORNL developed an electronic motor control called the dual mode inverter controller (DMIC) that makes permanent-magnet (PM) motors viable candidates for hybrid electric vehicles, including heavy-duty vehicles. PM motors have a very high power density and excellent efficiency and are about half the weight of a comparable induction motor.
- A new combustion regime has been documented that combines fuel injection timing, exhaust gas recirculation, and throttling strategies in diesel engines to achieve simultaneous reductions in oxides of nitrogen (NO*x*) of about 90% and reductions in particulate matter (PM) of about 45%, with no loss of efficiency.
- Technology and materials for manufacturing a carbon/graphite bipolar plate developed at ORNL have been licensed to Porvair Fuel Cell Technology, which is supplying the plates to major fuel cell manufacturers. The carbon/graphite bipolar plate meets or exceeds performance specifications at a low cost.

The Test Machine for Automotive Crashworthiness (TMAC) provides data on the crush behavior of advanced materials, such as composites and lightweight steel, at velocities ranging from quasi-static to greater than 8 m/s (18 mph) and a mean crush force up to 267 kN (60,000 lb).

Capabilities

ORNL's R&D for the DOE/EE FCVT Program capitalizes on significant expertise and facilities across the Laboratory. Materials research combines R&D expertise with modeling and simulation capabilities. Two major DOE national user facilities—the High Temperature Materials Laboratory and the National Transportation Research Center—play an important R&D role in DOE EERE's transportation program.

The High Temperature Materials Laboratory (HTML) helps solve materials problems that limit the efficiency and reliability of advanced energy conversion systems. The HTML comprises six user centers, which are available to researchers in industry, universities, and federal laboratories. Instruments available at the user centers have extensive capabilities for characterizing the microstructure, microchemistry, physical, and mechanical properties of materials over a wide range of temperatures.

- The Diffraction User Center includes both room-temperature and furnace-equipped X-ray, synchrotron, and neutron diffractometers, used for studies of materials properties at temperatures up to 2700°C in vacuum and up to 1600°C in air.
- The Machining, Inspection, and Tribology User Center conducts research on the manufacturability of ceramic and other difficult-to-machine materials and machining, inspection, and tribology of ceramics and other high-performance materials.
- The Materials Analysis User Center specializes in atomic structure, nanoscale composition, surface morphology, and surface chemistry investigations.
- The Mechanical Characterization and Analysis User Center specializes in the mechanical characterization of structural materials, including high-temperature materials.
- The Residual Stress User Center facilities include laboratory X-ray, synchrotron X-ray, and neutron diffraction instruments to investigate/determine strains near the surfaces of and throughout a material specimen.
- The Thermophysical Properties User Center facilities conduct research to establish the thermal stability, thermal expansion, specific heat, transformation temperatures, thermal diffusivity, and thermal conductivity of materials as a function of temperature and/or environment.

The National Transportation Research Center (NTRC) was established to develop and evaluate advanced transportation technologies and systems, utilizing state-of-the-art hardware and computing technologies. The NTRC houses 11 user centers, three of which directly support the FCVT Program.

- The Power Electronics and Electric Machinery Research Center is recognized worldwide for expertise in developing and prototyping advanced power converters, adjustable speed drives, and electric machines. The Center provides unique expertise in power converter topologies, thermal management, packaging technologies for electromagnetic interference minimization and for space and weight reduction, digital signal processing-based control techniques for motor drives, system energy management, flywheel energy storage applications and ultra-high-speed drive applications.
- The Fuels, Engines and Emissions Research Center specializes in the detailed characterization of internal combustion engine efficiency and emissions. The facility's comprehensive capabilities include bench-top engine exhaust simulators, a wide range of dynamometers, and full vehicles. The Center boasts several special diagnostic and measurement tools—including many rarely found at other facilities around the country, and some developed by Center staff—that aid in developing and evaluating engine and emission control technologies.

- The Composites Laboratory conducts research to establish dynamic material properties for structural materials under controlled, progressive crush experiments at programmable velocity profiles and high force levels typical of automotive crashes. The laboratory houses the Physical and Virtual Test Machine for Automotive Crashworthiness, which is a unique one-of-a-kind test device.

ORNL has significant expertise and capabilities that can support the Hydrogen, Fuel Cells, Infrastructure Technologies (HFCIT) Program. Unique facilities exist to support the development of hydrogen storage materials. ORNL hosts the High Flux Isotope Reactor and, soon, the Spallation Neutron Source for neutron diffraction that can provide pathways to correlate storage capacity of metallic and carbonaceous materials. ORNL also has a carbon materials research group, unique within the national laboratory complex. The alloy design group produces lab- to production-scale quantities of metal alloys and bulk amorphous alloys. Expertise is available to support hydrogen infrastructure R&D. ORNL is recognized for its leadership in photobiological and thermochemical cycles for hydrogen production and gas separation expertise, including the production of porous inorganic membranes for molecular sieving of hydrogen from mixed gas streams.

Operational and Support Needs

UT-Battelle and DOE have approved a plan for ORNL to lease a privately owned building, the National Transportation Research Center Annex, to be constructed adjacent to the NTRC. ORNL is in the process of selecting an engineering firm experienced in the design of turnkey transportation research facilities to assist in identifying the scope of the leased building, preparing a requirements document, and identifying necessary design features. The Annex will provide expansion room for the Fuels, Engines, and Emissions Research Center, as well as the capability for an R&D program on fuel cell systems for transportation applications. Support is needed for equipping the facility to enable these research missions.

Key Partnerships

ORNL is a partner in DOE's FreedomCAR and 21st Century Truck Partnerships. These are broad collaborative programs that involve extensive partnerships with industry, universities, and other national laboratories. Key partners include Argonne National Laboratories, National Renewable Energy Laboratory, Pacific Northwest National Laboratory, Sandia National Laboratories, numerous universities, United States Council for Automotive Research, engine manufacturers, truck manufacturers, ChevronTexaco, ConocoPhillips, ExxonMobil, Shell Hydrogen, and other industrial partners.

Industry, Buildings, and Federal Facilities

Primary Roles in the Context of DOE Mission Objectives

ORNL is an R&D partner with the Industrial Technologies Program (Industries of the Future, Industrial Materials for the Future, Sensors and Automation, and Technology Delivery). Working with energy-intensive industries, ORNL has helped to increase the energy efficiency of processes and also accrue economic and environmental benefits. Development of new materials that can better withstand high temperatures and highly corrosive environments is a key ORNL role, especially in R&D related to kraft recovery boiler tubes; melting and process furnaces; chemical

Program Area	ORNL Roles
Industrial Technologies	• Industries of the future process and systems development • Industrial materials for the future (alloys, composites, and coatings) • Industrial sensors and controls • Technology delivery (process tools and direct energy use evaluations)
Building Technologies	• Advanced space conditioning and refrigeration equipment, thermal distribution and appliances • Building thermal envelope and materials
Weatherization and Intergovernmental	• Evaluation of Weatherization Program impacts • International clean energy technology transfer and capacity building
Federal Energy Management	• Geothermal heat pumps at federal facilities • Distributed generation, including combined heat and power and other EERE technologies • Implementation of federal alternative financing authorities

reaction vessels; and materials processing. Improved processing methods including microwave and electron beam technologies, distillation and separation systems, and metals processing are also focus areas. Sensing and automation technologies are critical to future energy-efficient processing capabilities, and ORNL will play a major role in their development. One of the focus areas is evaluating candidate industrial wireless systems in a simulated industrial environment. ORNL is also developing software tools to evaluate motor, steam, compressed air, process heating, and boiler systems. Finally, ORNL is working with student engineers in the Industrial Assessment Center to encourage professional development and to help transition them into a career in energy.

ORNL research in building technologies spans several areas. Advanced space conditioning, refrigeration, thermal distribution, and appliance technologies are examined to improve energy efficiency and indoor environmental quality. Materials research focuses on technologies for high-efficiency, long-lived building insulation and moisture control. ORNL's building envelope research examines how buildings function as an integrated whole, reflecting the interactions between roofs, windows, walls, and other building elements. Retrofits to improve energy efficiency in existing buildings are also studied to determine how to obtain the most cost-effective results. Other areas include research on innovative materials and technologies for zero energy buildings, including hybrid lighting concepts.

ORNL provides outside program evaluation to DOE's Office of Weatherization and Intergovernmental Program (OWIP) for its full range of programs and in particular on a continuing basis for its low-income Weatherization Assistance Program and the State Energy Program. The Laboratory's engineers develop and maintain advanced residential building audits and end-use monitoring techniques, as well as provide technical assistance with market analysis, household energy budget projections, technology assessment, and resource leveraging.

ORNL supports the DOE Federal Energy Management Program's mission of transferring energy efficiency and renewable energy technologies to federal agencies for use in their buildings, industrial facilities, and transportation systems.

Objectives and Strategies

Through collaborative R&D, ORNL will deliver breakthrough technologies that will modernize energy efficiency in the nation's industries, homes, commercial buildings, and federal facilities.

Objective 1: *Collaborate in R&D partnerships with industries and universities in order to develop and help implement energy efficient technologies in the industrial sector.*

Strategy

- Communicate and participate with various industrial sectors in identifying needs and the development of R&D solutions and plans.

Objective 2: *Strengthen and expand ORNL's collaborations with TVA in the development and deployment of energy-efficient technologies.*

Strategy

- Conduct annual strategic planning meetings with TVA to review activities and brainstorm new ideas.
- Initiate collaborative field testing of the frostless heat pump and hybrid solar lighting.

Objective 3: *Apply ORNL world-class materials expertise to improving the cost performance of solid state lighting.*

Strategy

- Utilize ORNL discretionary resources (e.g., program development or "seed" funding) to initiate a research effort in the area of solid state lighting.

Objective 4: *Expand ORNL's multidisciplinary capabilities to bridge the gap between basic and applied research on energy-efficient technologies and transfer to mainstream utilization in federal facilities and the economy at large.*

Key Accomplishments

There have been numerous ORNL R&D accomplishments in the industrial, buildings, and federal sectors. In the industrial sector:

- A complete set of nickel aluminide rolls (an ORNL invention) has performed successfully in a commercial-scale steel heat treating furnace.
- Microwave pretreating of wood has been shown to use significantly less energy and up to 10% less chemicals in the forest products pulping process.
- Microstructural modeling in the aluminum area proved that in-line annealing can eliminate two heat-treating operations.
- New boiler tube materials are being implemented in nine pulp and paper mills.
- Improvements in distributed wireless sensor systems have been demonstrated to save significant energy in wood drying and steel processing.
- Best practices and related activities have lead to quantified increased energy efficiencies in numerous industrial sectors.

In the buildings sector:

- ORNL's research on advanced refrigeration technologies was designated in 2001 as one of DOE's top five energy accomplishments.
- Research on heat-pump water heaters (HPWHs) earned an R&D 100 award in 2001; studies have revealed that HPWHs are over 50% more energy efficient than water heaters that use electric resistance.

In the Weatherization and Intergovernmental Program:

- ORNL's National Energy Audit (NEAT) is currently being used to weatherize low-income homes in 35 states.
- ORNL has been involved in successful clean energy technology activities with over 40 countries during the last 5 years.

In the federal sector:

- In recent years private financing of building retrofits through Energy-Savings Performance Contracts (ESPCs) has been the largest source of retrofit funding for federal agencies, and ORNL has facilitated about one-third of the $580 million national total investment under DOE's Super ESPC program through FY 2003.
- The ORNL-led initiative to help federal agencies lead by example in the use of geothermal heat pumps (GHPs) has resulted in over $100 million being invested in projects using this technology in the last 2 years, exceeding GHP investment in the previous 10 years.

Strategy

- Establish new research facilities at the EREL and upgrade equipment and capabilities at the Metals Processing Laboratory Users Facility and the Buildings Technology Center.
- Build confidence in the use of advanced EERE technologies through applications research and technical assistance to federal agencies and other users.
- Build technology transfer partnerships between the Federal Energy Management Program (FEMP), EERE research programs, industry, and FEMP's agency customers and alternative financing private partners.

The heat-pump water heater saves 5 to 10 kWh of electricity daily.

Capabilities

ORNL is nationally and internationally recognized in the area of materials science R&D. Unique capabilities include materials processing (alloys, ceramics, coatings, and refractories), characterization (corrosion science, mechanical properties), joining (nearly all techniques), and materials and materials process modeling (from phenomenological to hierarchical multi-length scale models).

In addition to extensive modeling capabilities, ORNL's expertise in building sciences includes HVAC, refrigeration, and appliance design, optimization and control; benchmarking and monitoring building thermal performance; moisture analysis and control; whole building sustainable design, construction management, and commissioning; and retro-commissioning or continuous-commissioning of existing energy-consuming systems.

ORNL is also expert on alternative financing authorities for building retrofits, including Energy Savings Performance Contracts, Utility Energy Services Contracts, and out-lease property management.

Operational and Support Needs

Support is needed to maintain the state-of-the-art research equipment at two national user facilities sponsored by DOE/EE, which support energy-efficiency research in industry and buildings.

- The Metals-Processing Laboratory Users (MPLUS) Facility provides industry and academia with unique opportunities to address technology-related issues to solve metals and other materials processing problems from an integrated approach. MPLUS includes four primary user centers: Processing, Joining, Characterization, and Process Modeling.
- The Buildings Technology Center (BTC) is the premier U.S. research facility devoted to the development of technologies that improve the energy efficiency of residential and commercial buildings. The BTC is housed in a cluster of six buildings offering 20,000 square feet of space and state-of-the-art experimental facilities, including a large-scale climate simulator.

Key Partnerships

Partnerships are critically important to the Industrial Technologies efforts. Nearly every R&D project has industrial or university partners, with many projects having multiple partners. Over 100 industries and universities are currently partnering in these projects. Collaborations with industry groups and associations are also key. In addition, important partnerships exist with several state energy agencies and universities, including memorandum of understanding agreements in place with Secat, North Carolina State University, and Energy Industries of Ohio.

ORNL has established strong partnerships with the buildings industry including equipment and materials manufacturers. In addition, a close alliance with the Tennessee Valley Authority has been established that has led to numerous technical successes.

ORNL's key partners in the Federal Energy Management Program (FEMP) are NREL, LBNL and PNNL, the DOE Regional Offices, private sector energy service companies, and utilities that finance pay-from-savings projects.

Renewable Energy Resources

Primary Roles in the Context of DOE Mission Objectives

Biomass energy systems use the solar energy captured by green plants in biomass to produce electricity, heat, liquid transportation fuels, and biobased chemicals. The joint ORNL and Idaho National Engineering and Environmental Laboratory (INEEL) Biorefinery Feedstock Supply Program conducts R&D to increase the supply of safe, cost-effective, sustainable biomass for energy and bioproduct production. The Laboratory also conducts R&D on advanced bioprocessing, on bioproducts development, and on developing improved materials for biomass gasification, including containment materials that resist erosion in biomass gasifiers.

Program Area	ORNL Roles
Biomass	• Resource and environmental analysis • Feedstock engineering • Bioprocessing and materials for biomass gasification
Wind and Hydropower	• Advanced hydropower technology • Integrated dispatch of wind and hydro • Ancillary service and system reliability impacts of integrating wind into the bulk power system
Solar	• Hybrid solar lighting
Geothermal	• Geothermal heat pump technology

ORNL has supported DOE's hydropower research and development since 1977 by focusing on ways to reduce environmental impacts and improve net benefits of this important renewable resource. In recent years, hydropower R&D has grown substantially in support of advanced turbine development and testing. ORNL's current research includes computational modeling, laboratory studies of the response of fish to physical stress, and field studies to evaluate environmental mitigation technology like fishways.

ORNL is supporting expansion of solar energy use by developing a hybrid solar lighting (HSL) center of excellence and expanding research into other hybrid solar technologies and photovoltaic (PV) materials / processing technologies. The strategy is to collaborate with SunLab (NREL and Sandia) and industry in each of these areas.

ORNL supports DOE's wind program and collaborates with NREL in the analysis of integrating wind power with the electric power system. Specific areas of research include the analysis of how wind plants interact with the regulation and load following requirements of the bulk power system. ORNL is currently performing analysis in support of California's least-cost-best-fit renewables portfolio standard.

Key Accomplishments

- ORNL has developed the largest suite of molecular markers for poplar and switchgrass in the United States, a saturated genetic linkage map for poplar with quantitative trait loci for growth identified, and genetic sequencing capability for plant sciences research.
- In its hydropower research, ORNL has recently completed reports on unsteady computational fluid dynamics (CFD) modeling applications of turbulent flows inside turbines (with Georgia Tech), regulatory options for mitigating dissolved oxygen problems at dams, and new analysis methods to detect indirect mortality to fish passing through turbines.
- In September 2002, ORNL installed the first hybrid solar lighting (HSL) system at the NTRC. The sunlight collector consists of a parabolic primary mirror that tracks the sun throughout the day and a secondary mirror that reflects the visible portion of the converging sunlight into eight large core optical fibers.

ORNL staff have supported DOE's geothermal heat pump (GHP) research and development since the late 1970s, though the technology has had different names (solar-assisted heat pumps, ground-source heat pumps) and DOE sponsors (Solar, Buildings, Geothermal) over time. Recent work has focused on developing reliable methods for determining thermal properties of soil and rock formations from short-term in situ tests, sizing vertical ground heat exchangers, and developing techniques for estimating the energy and cost savings of GHP systems applied to various types of buildings.

Objectives and Strategies

In collaboration with industry, ORNL seeks to develop renewable energy technologies that can tap America's vast and diversified domestic renewable resource base.

Objective 1: *Realign ORNL's biomass research with DOE/EE's new focus on developing cost-competitive biorefinery technologies that co-produce bio-based fuels, products, or power.*

Strategy

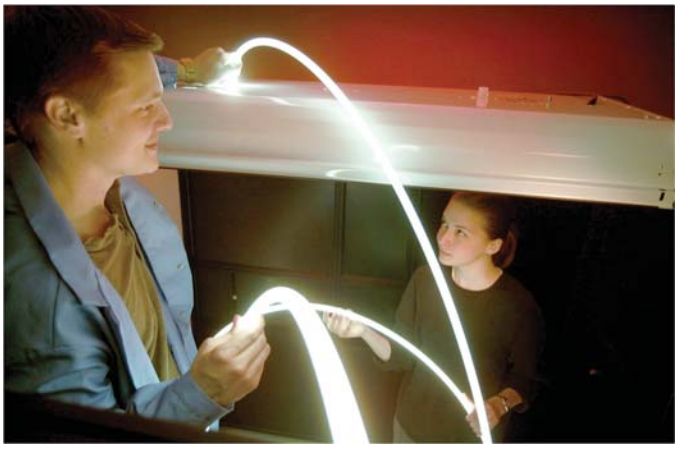
- Develop strategic industrial partnerships in the bioprocessing area.

Objective 2: *Support DOE/EE's initiative to re-institute a geothermal heat pump R&D program.*

Strategy

- Update technology assessment and impacts data from previous programs and innovative crosscutting multidisciplinary planning to help justify the new program.

Capabilities



Prototype hybrid lighting fixtures are being tested at ORNL.

ORNL has developed economic and transport models for assessing biomass resource availability and has the capability to link those to environmental models to assess regional impacts. ORNL supports hydropower R&D with biologists, environmental engineers, hydrologists, economists, computer scientists, and power systems engineers. ORNL capabilities relevant to solar technologies include photonics, fiber optics, solid state devices, power systems, novel materials, and material processing techniques. ORNL supports geothermal heat pump R&D with expertise in advanced materials for drill bits and other components, heat pump and ground heat exchanger design, modeling, data collection and analysis, and integration into sustainable building systems.

The Bioprocessing Research and Development Center (BRDC) includes laboratories for the investigation of advanced bioprocessing concepts using stirred-tank and columnar bioreactors and a fermentation pilot plant for large-scale batch and columnar experiments at a <500-L scale. Other research and support laboratories are available on-site.

The High Temperature Materials Laboratory has state-of-art equipment for testing material properties and capability of simulating a gasifier environment for testing refractory materials.

Microwave/rf microstructure modification facilities allow testing of pretreatment of wood for bio-pulping, hydrolysis, and fermentation processes.

Operational and Support Needs

ORNL's Aquatic Research Laboratory requires capital investment to replace aging water treatment and supply equipment to be used in studying the response of fish to turbulent flow regimes inside hydropower turbines. Hybrid solar lighting capital funding is needed to equip the HSL laboratory.

Key Partnerships

The National Bioenergy Center was established in November 2000 with the NREL and ORNL as co-leaders. It has since expanded to include INEEL as a joint partner with ORNL on feedstock research. The ORNL materials research for biomass gasification is being done in partnership with about 15 forest products companies and gasifier equipment suppliers.

In hydropower research, ORNL's partners include Georgia Institute of Technology and Voith Seimans Hydro Power Generation for CFD modeling, and the Tennessee Valley Authority for flow

measurement instrumentation. ORNL also works closely with INEEL, Pacific Northwest National Laboratory (PNNL), and NREL. Wind partnerships include NREL, the Utility Wind Interest Group, and California's Energy Commission, Public Utilities Commission, and the Independent System Operator (ISO). Partnerships in the solar energy area include more than 25 industry, university, and SunLab partners associated with the Hybrid Lighting Partnership.

In the geothermal heat pump area, DOE's Geothermal Technologies (GT) Program and Federal Energy Management Program (FEMP) have forged a strong partnership for technology transfer and deployment through federal agency use of GHPs in their own facilities. ORNL's other partners include the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), the International Ground-Source Heat Pump Association (IGSHPA), the Geothermal Heat Pump Consortium (GHPC), utilities, energy service companies, and manufacturers of water-source heat pumps, ground heat exchanger pipe, and drilling equipment.

Electric Transmission and Distribution

Strategic Objectives

The National Transmission Grid Study (NTGS), issued in May 2002, outlined 51 recommendations to help ensure a robust and reliable electric grid for the twenty-first century. To ensure that these recommendations were implemented, the NTGS stated that DOE would "combine its divergent electricity delivery system resources into a single, focused Office of Electric Transmission and Distribution."

This new office has four primary functions: Modeling and Analysis; Research and Development (R&D); Electricity Import/Export Authorization; and Coordination with the Power Marketing Administration (PMA) liaison office and the Bonneville Power Authority.

ORNL's strategic objective is to become OETD's "laboratory of choice" for R&D on new technologies that increase the reliability, capacity, and efficiency of the transmission and distribution system. This includes research to integrate energy storage, distributed energy resources, and control technologies into the transmission and distribution grid.

Primary Roles in the Context of DOE Mission Objectives

ORNL's R&D for the OETD focuses on technologies for electric transmission and distribution.

Program Area	ORNL Roles
Electric Transmission and Distribution	• High-temperature superconductivity for electric systems • Advanced conductors, power electronics, and modeling strategies that expand transmission and distribution capacity • Load as a resource analysis and design to help enable utilities to find alternatives to spinning reserves

Objectives and Strategies

ORNL is proposing an initiative in grid modernization designed to build capabilities and programs in support of OETD's mission. This initiative is built around the following objectives. The strategies for accomplishing these objectives are described in the Grid Modernization Initiative.

Objective 1: *Expand ORNL's capabilities in T&D–related materials and modeling research beyond high-temperature superconductors.*

Objective 2: *Establish ORNL project for Interconnection-wide (IW) Energy Management System (EMS) for real-time grid operation and control.*

Objective 3: *Establish ORNL research area for power system control information design.*

Objective 4: *Establish new ORNL thrust area in research and development of low-cost, ubiquitous sensors and communication technologies.*

Objective 5: *Establish new research facilities—the Energy Reliability and Efficiency Laboratory (EREL), the National Transmission Technology Research Center (NTTRC), and the National Energy Assurance Analysis Center (NEAAC).*

Key Accomplishments

- ORNL second-generation high-temperature superconducting (HTS) wire technology has been adopted, improved upon, and implemented in long-length, reel-to-reel processes by U.S. industry. This achievement was accompanied by unprecedented uniformity along the tape length using a reproducible process that American Superconductor Corporation (AMSC) believes is industrially scalable.
- The world's longest running HTS cable system continues to break performance and reliability records at industrial partner Southwire Company, with over 20,000 hours providing full power to three manufacturing plants in Georgia. The terminations for this system were designed by ORNL, and the technology was transferred to U.S. industry. The system has been running unattended, carrying up to 20 megavolt amperes (MVA), since June 2001.
- The NTTRC became operational in March 2003 to address the extensive needs of the overhead transmission network for relieving transmission congestion, increasing reliability, and facilitating commercial electric power transactions.

Capabilities

The Electric Transmission and Distribution Program utilizes a unique research facility that was specifically developed for the OETD. The Power Conductor Accelerated Test Facility (the first component of the NTTRC) became operational in March 2003 to address the extensive needs of the overhead transmission network for relieving transmission congestion, increasing reliability, and facilitating commercial electric power transactions. Controlled testing is critical in order for utilities to gain the confidence required before system reliability can be entrusted to these new technologies.

The program also draws from the expertise and facilities available from other parts of the Laboratory, including the High Temperature Materials Laboratory, which provides state-of-the-art materials characterization and other unique laboratories for the Superconductivity Program.

Operational and Support Needs

To be successful in achieving the strategic goals for the OETD, ORNL needs a major new facility: the Energy Reliability and Efficiency Laboratory (EREL). This facility will focus on three critically important R&D areas: electricity transmission and distribution, distributed energy resources, and net zero-energy building systems. The facility is planned to provide entirely new R&D capabilities not available elsewhere in the DOE complex, including a full spectrum of equipment for continuous processing and characterization of second-generation HTS tape; an isolated power line for electricity transmission and distribution research including impulse testing to 500 KV to determine breakdown properties; and facilities for optimizing the integration of distributed generation, power electronics, and thermally activated equipment. More than 80% of the new building will be laboratory space, all of which will be available for collaborative R&D with industrial, university, and other partners through designation as a National User Center. Project engineering and design funds are proposed in the Administration's FY 2004 budget request. Construction funds are needed in FY 2005 and FY 2006.

To be successful, support is also needed for the Energy Security through Grid Modernization Initiative. This initiative includes materials R&D for modernizing and expanding electric transmission and distribution.

Key Partnerships

Partnerships have been established with U.S. manufacturers, energy service providers, national laboratories, universities, utilities regulatory commissions, and independent system operators to advance technology, reduce development and operating costs, and maintain a competitive position with the most efficient and cleanest generation, transmission, and distribution systems. Key industrial partners include Southwire, Waukesha, General Electric, American Superconductor, Norton, Allegheny Teledyne, Digi-Log, and Carrier.

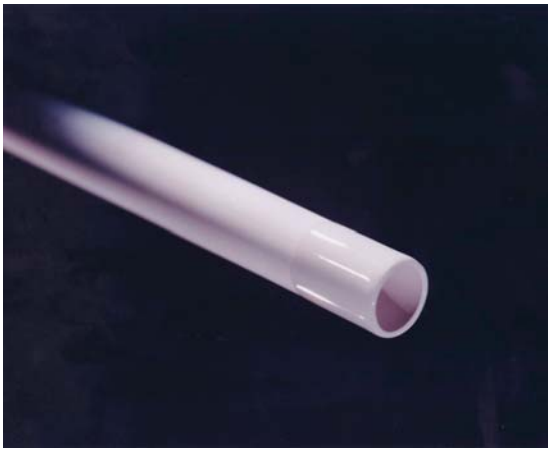
ORNL's proposed EREL will propel DOE/OETD's research agenda forward.

Fossil Energy

Strategic Objectives

The ORNL Fossil Energy (FE) Program is strategically aligned with and supportive of the DOE Office of Fossil Energy (DOE-FE) programs in Coal and Power Systems, Natural Gas and Petroleum Technologies, and Petroleum Reserves. ORNL's work is directed toward the major DOE-FE objective of eliminating environmental impacts as barriers to fossil fuel production and use, while maintaining the availability and affordability of these fuels. This objective includes reducing carbon emissions. The ORNL FE Program is committed to improving the science base that can be used to accomplish this objective, with an emphasis on six key areas.

1. ORNL will lead the development of structural and functional materials that will satisfy the requirements of the major technology/line programs being pursued by DOE-FE on the time schedule defined in the Advanced Research Materials Program R&D Road Map.
2. ORNL will lead a well-integrated team in the development of porous inorganic membranes for hydrogen separation.
3. ORNL will deliver new understanding of the formation, structure and characteristics, and stability of methane hydrates, which represent a potentially enormous source of natural gas.
4. ORNL will develop innovative approaches to carbon sequestration.
5. ORNL will continue its collaboration with the National Energy Technology Laboratory (NETL) to implement a new initiative on sensors and controls for fossil energy system applications.
6. ORNL will expand its work in computational modeling and simulation of fossil energy systems in partnership with NETL to achieve more rapid and precise simulation of complex energy problems.



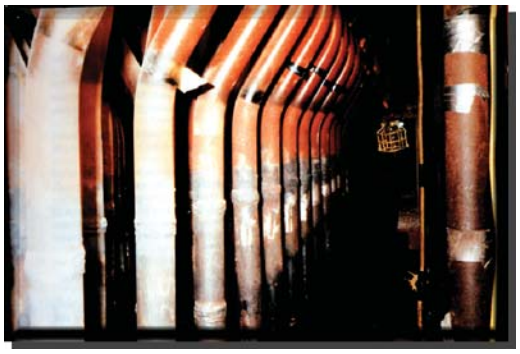
Photograph of an inorganic hydrogen separation membrane. This membrane is based on the world's most advanced porous membrane technology. These types of membranes have the potential to revolutionize the gas separations industry, including replacement of many high energy–consuming processes such as distillation. The market potential for these membranes is estimated at several billion dollars annually.

Primary Roles in the Context of the DOE Mission

DOE-FE R&D programs address critical issues in coal and power systems, natural gas and petroleum, fuels including hydrogen, and petroleum reserves. ORNL is engaged in all of these programs.

1. **Materials R&D.** ORNL has a major technical management and R&D role in DOE-FE's only program devoted exclusively to the development of materials for fossil energy applications. Our materials R&D is focused on both structural (primarily high-temperature) materials and functional materials (i.e., materials that perform process functions). Through its technical management role, ORNL maintains awareness of the materials R&D needs of the major power generation and fuels programs within DOE-FE. Working in partnership with DOE-FE and

NETL, ORNL manages a strongly supported program that is comprehensive in R&D activities and diverse in types of performers, spanning 7 national laboratories and more than 50 industry and university research groups.



Installation of ORNL-developed 9Cr-1Mo alloy boiler tubes in TVA's Kingston Steam Plant. This alloy is in use in power plants throughout the world and is the standard for coal-fueled steam power plants. Sales of components made of this alloy have exceeded $1 billion.

2. **Inorganic Membranes for Gas Separation.** DOE-FE is engaged in establishing a pathway to the hydrogen economy through the development of new and innovative hydrogen production processes from coal via gasification and natural gas via reforming. ORNL is establishing a major role in all aspects of hydrogen production, including the development of improved and compact fuel processors, hydrogen storage media, and hydrogen separation and purification materials and devices. R&D on membranes for gas separations has confirmed the feasibility of these membranes as molecular sieves for hydrogen separation and purification. Work is under way to optimize these porous membranes for separation effectiveness and permeance/gas flux.
3. **Methane Hydrates.** ORNL is actively engaged in the DOE-FE methane hydrates program, with three projects now under way: one directed toward understanding the formation and characteristics of this material, one in collaboration with the Idaho National Engineering and Environmental Laboratory (INEEL) on collection of naturally occurring deposits of methane hydrates, and one directed toward neutron diffraction characterization methods.
4. **Carbon Sequestration.** Carbon sequestration is a preferred approach to mitigating the potential effects of carbon dioxide emissions. ORNL is pursuing innovative approaches to carbon dioxide separation and capture and in terrestrial ecosystems and geologic sequestration approaches. An innovative mineral carbonation approach, developed using internal funding, is the subject of a proposal to extend the development of this concept. Three carbon dioxide separation and capture projects are being conducted with industrial sponsorship, including two funded by BPAmoco on behalf of the CO_2 Capture Project, a consortium of eight major energy companies, and one sponsored jointly by DOE-FE and ChevronTexaco.
5. **Sensors and Controls.** Sensors and controls are recognized as critical supporting technologies for advanced fossil energy systems. Because of the harsh environments and extreme temperatures encountered in many of the emerging advanced fossil energy systems, currently available sensors and controls are often not sufficiently rugged and robust to function for needed time periods. Improved materials and designs, as well as innovative approaches to nonintrusive temperature measurement, are needed. On the basis of internal and external workshops and a sensors and controls R&D needs assessment, ORNL is now moving into the program planning and development stage and expects to submit proposals for work in this area.
6. **Computational Modeling.** Advanced computer simulations are now recognized as invaluable elements for the timely and cost-effective development of clean, reliable supplies of fossil energy. ORNL and NETL have formed an alliance to leverage the resources available for simulations of interest to DOE-FE. Simulation tools developed by the Office of Science–supported SciDAC for key processes such as coal gasification will enhance and improve the simulation of these fossil energy systems.

Objectives and Strategies

Objective 1: *Expand and strengthen the Materials R&D Program.*

Strategy

- Continue the development and implementation of the Advanced Research (AR) Materials Program road map and provide linkages to line program road maps.
- Build collaborative R&D programs that engage the national laboratories, universities, and industrial research organizations.
- Continue structural and functional materials R&D to address critical high-temperature-materials issues of new FE programs related to hydrogen processing and use.

Objective 2: *Complete the integration of the Inorganic Membrane Technology Laboratory (IMTL) into ORNL.*

Strategy

- Move the IMTL from the East Tennessee Technology Park to the new Engineering Technology Facility at ORNL.
- Streamline the process for obtaining classification and nonproliferation reviews of products of interest to DOE, particularly DOE-FE, and other agencies and nongovernmental organizations.
- Establish a mechanism for early testing and evaluation of prototype ORNL inorganic membranes in separations systems.

Objective 3: *Secure a leading role in simulations of methane hydrate formation and in characterization and properties determinations.*

Strategy

- Expand collaborative efforts with other national laboratories, universities, and industry groups using the Seafloor Process Simulator.
- Build on the results of neutron diffraction studies of methane hydrates and expand into other characterization and physical properties measurements.

Objective 4: *Extend ORNL's efforts in carbon sequestration R&D, particularly in separation and capture and in terrestrial ecosystems and geologic sequestration.*

Strategy

- Build collaborations on the use of electrical swing adsorption as an approach to carbon dioxide separation and capture.
- Strengthen and expand the cooperative efforts between DOE's Office of Science and Office of Fossil Energy on sequestration in terrestrial ecosystems.

Recent Accomplishments

- Sales of components/products based on ORNL Fossil Energy Materials Program developments exceed $1.5 billion.
- Innovations generated through the FE AR Materials Program have won a total of nine R&D 100 Awards.
- Fifteen products from the FE work on inorganic membranes have been approved for commercial production.
- Iron aluminide filters developed by ORNL and Pall Corporation have become the material and filters of choice for coal combustion and coal gasification applications.
- Completion of construction and pressure testing on the geo-sequestration simulator will allow us to examine interactions between injected CO_2 with natural and added conservative tracers, with native subsurface media, and with representative brine or hydrocarbon-containing solutions.
- Proof-of-concept work is complete on a semi-continuous furnace to economically produce silicon carbide fibrils, and this development has the potential to revitalize the reinforced ceramics industry.

- Build a fundamental research program on geological sequestration, using as a model the current work on coal bed methane and mineral carbonation.

A commercial hot gas "blowback" filter system (Pall Corporation's Accusep™ Filter System) based on ORNL's inorganic membrane technology. Pall Corporation, the largest filter manufacturing company in the world, is an industrial partner of ORNL's Inorganic Membrane Technology Laboratory.

Objective 5: *Establish a collaborative program on sensors and controls for advanced fossil power generation systems.*

Strategy

- Determine sensors and control R&D needs for advanced power generation systems through internal workshops.
- Establish consensus on sensors and controls R&D needs and organizational competencies to address these needs through DOE meetings and workshops.
- Define and develop research plans for specific areas of interest.

Objective 6: *Dramatically expand the availability of simulation tools for key processes such as coal gasification that will enhance and improve the simulation of fossil energy systems.*

Strategy

- Identify those computational energy systems collaborations under the NETL-ORNL alliance that are applicable to DOE-FE.
- Use the SciDAC-developed computational methods to address system simulation issues that are relevant to DOE-FE.
- Validate computational results through experiments at NETL and / or ORNL.

Capabilities

Materials R&D: Alloy design and development, materials characterization, and materials compatibility. Materials processing of alloys, ceramics, catalysts, sensors, and thin films offers significant advantages from development through technology transfer.

Separations Materials and Processes: Inorganic Membrane Technology Laboratory, High Temperature Materials Laboratory, separations capabilities. DOE's huge investments in gas separation technology, particularly porous inorganic membranes for uranium enrichment in its nuclear power programs in Oak Ridge, are a major asset to separations research.

Methane Hydrates and Carbon Sequestration: Capabilities distributed across the Laboratory. ORNL has built and made operational a high-pressure system called the Seafloor Process Simulator, which is used to synthesize methane and other gas hydrates under conditions simulating those that exist on the seafloor.

Sensors and Controls: Capabilities for materials development and instrumentation needs.

Computational Modeling: ORNL has considerable staff resources and computational hardware that can be used to complement and supplement NETL's in-house capabilities for implementing and validating the SciDAC tools on specific fossil simulations.

Operational and Support Needs

Move the Inorganic Membrane Technology Laboratory from the East Tennessee Technology Park to the new Engineering Technology Facility at ORNL. Modify the Seafloor Process Simulator to allow sampling and maintenance of gas hydrates under conditions of their formation. Complete the installation of the functional materials and processes laboratory.

Key Partnerships

Materials R&D: NETL, ANL, PNNL, LANL, SNL, INEEL, Ames

Separations Materials and Processes: NETL, Pall, ExxonMobil, ChevronTexaco, Air Products and Chemicals Company, Praxair

Methane Hydrates: NETL, LBL, PNNL, ChevronTexaco

Carbon Sequestration: NETL, LBL, LANL, Alberta Research Council, Schlumberger, Oklahoma State University, Columbia University

Sensors and Controls: NETL

Computational Energy Systems: NETL

Commercial iron aluminide filter used for hot-gas particulate filtration in coal combustion and coal gasification systems. Developed under a joint collaboration with Pall Corporation, the iron aluminide filter has become the filter of choice for these applications.

Nuclear Energy, Science and Technology

Strategic Objectives

Both the United States and the international community are seeking improved and more versatile means to produce energy economically without releasing carbon dioxide and other greenhouse gases into the biosphere. The Generation IV International Forum (GIF) seeks to leverage international research capabilities to develop the next generation (designated Generation IV) of nuclear energy systems. These Generation IV nuclear energy systems would provide sustainable, safe, reliable, and economical nuclear energy that can provide a variety of energy products, including electricity and hydrogen. The DOE Office of Nuclear Energy, Science and Technology (DOE-NE) is leading an international collaborative research effort within the GIF.

Generation IV nuclear energy systems are not simply reactors but will address all aspects of nuclear energy generation, including the fuel cycle and waste disposal. These nuclear energy systems must be

- sustainable in terms of assured fuel supply, minimized waste production to reduce the long-term stewardship burden and to protect the public health and the environment, and reduced risk for the theft or diversion of weapons-usable materials;
- demonstrably safe and reliable with a very low likelihood and degree of reactor core damage and with no need for offsite emergency response; and
- economical, as demonstrated by having a clear life-cycle cost advantage over other energy sources.

Six candidate reactor systems have been identified; the candidate system of primary interest to DOE is the Very High-Temperature Gas-Cooled Reactor (VHTR) for cogeneration of electricity and hydrogen.

To support sustainability within the Generation IV program and to eliminate the need for a second repository for spent nuclear fuel, DOE-NE is also pursuing the Advanced Fuel Cycle Initiative (AFCI) to develop technologies that can reduce the volume and long-term toxicity of high-level waste from spent nuclear fuel, reduce the long-term proliferation threat posed by plutonium in spent fuel, and support the recovery of the energy content in spent nuclear fuel (which is equivalent to 6 billion barrels of oil).

DOE-NE is supporting the National Aeronautics and Space Administration (NASA) in its effort to define and develop the radioisotope power systems (RPS) and the fission power systems for future missions of exploration in both near and deep space, designated “Project Prometheus.” RPS development will focus on two technologies, the multi-mission radioisotope thermoelectric generator (MMRTG) and the Stirling radioisotope generator (SRG), which are expected to improve the efficiency and utility of NASA’s current systems. The fission power and propulsion research will focus on developing the nuclear systems needed for revolutionary capabilities in space exploration.

Finally, DOE-NE retains key missions to provide a continuing, reliable source of isotopes for industrial, medical, and defense applications. ORNL intends to deliver R&D and nuclear energy technologies that support the Generation IV and AFCI program, space applications, and isotopes production.

Primary Roles in the Context of DOE Mission Objectives

- ORNL leads the development of the research program for selecting and qualifying the high-temperature materials for Generation IV nuclear energy systems, including the materials that will be required for energy conversion and hydrogen production.
- ORNL is developing the cost guidelines for judging the economic viability of the Generation IV nuclear energy systems.
- ORNL is providing the research for advanced coated-particle fuel fabrication, including the development of characterization methods to support quality assurance in commercial deployment for the Gas Turbine Modular High Temperature Reactor (GT-MHR) under the Advanced Gas-cooled Reactor Program for DOE's Nuclear Power 2010 Initiative and for the VHTR under Generation IV.
- For the AFCI, ORNL conducts the research needed to revolutionize aqueous separations processes to provide proliferation-resistant fuel cycles.
- ORNL continues to provide the medical community with reliable, secure, and cost-effective supplies of diagnostic and therapeutic radioisotopes.
- Drawing on its isotopes programs, ORNL offers the national security community a resource of knowledge and expertise on radioisotopes of concern for radioactive dispersal devices (RDDs).
- As part of DOE's effort to assist NASA in the planning and execution of Project Prometheus, ORNL is responsible for missions and systems safety assessments. ORNL is working with NASA's George C. Marshall Space Flight Center to develop a breakthrough multi-megawatt space power reactor design methodology and a significantly improved multi-megawatt space power reactor concept.
- ORNL continues to support NASA's RPS Program by producing space-flight-quality iridium-alloy clad vent sets (CVS) for encapsulating the ^{238}Pu pellets for the NASA New Horizons Program. ORNL provides the space and defense community with the technology, components, and capacity to produce ^{238}Pu required to meet diverse mission needs for safe, reliable, robust, and remote power systems using radioisotopes.
- ORNL supports the critical infrastructure (hot cells, analytical and experimental facilities, simulation platforms) needed for advances in nuclear energy technologies for Generation IV, AFCI, isotopes production, and space applications.
- ORNL provides the systematic integration of technical expertise from the Fossil Energy and Fusion Energy Materials Programs and the National Security and Nonproliferation Programs to facilitate advances in high-temperature reactor development and proliferation-resistant nuclear technologies.

View inside the new uranium-coated-particle laboratory for development of advanced gas-cooled reactor fuels.

ORNL's primary roles are as follows:

Program	ORNL Roles
Technology Advanced Nuclear Research Nuclear Energy Research Initiative (NERI) International NERI Generation IV Nuclear Energy Systems AFCI Nuclear Power Systems Advanced Gas-cooled Reactor (AGR) Program	• Provide the technical lead for the Generation IV materials R&D program. • Provide the technical lead for AFCI aqueous processing technology. • Provide the technical lead in developing advanced coated-particle fuels for the GT-MHR and the Generation IV VHTR and Gas-Cooled Fast Reactor (GFR). • Provide key R&D for the Generation IV VHTR, GFR, and Molten Salt Reactor activities.
Operations and Management Nuclear Fuel Supply Security Advanced Gas Centrifuge	• Provide for domestic enrichment supply by developing advanced technology under the U.S. Enrichment Corporation (USEC) CRADA.
Nuclear Operations Nuclear Facilities Management Isotopes Program	• Continue the production of industrial and medical isotopes to meet DOE commitments.
Space & Defense Power Systems Radioisotope Thermoelectric Generator (RTG) Program	• Support the NASA-DOE fission power systems initiative. • Produce the RTG iridium and graphite components. • Develop the future ^{238}Pu production capacity.

Objectives and Strategies

Objective 1: *Expand ORNL roles in Generation IV nuclear energy systems development, AFCI, and hydrogen co-generation.*

Strategy

- Secure projects that apply ORNL's distinctive capabilities to the Very High-Temperature Reactor (VHTR), the Gas-Cooled Fast Reactor (GFR), the Molten-Salt Reactor (MSR), and the Advanced High-Temperature Reactor (AHTR).

Objective 2: *Consolidate and expand ORNL's R&D in high-temperature materials, graphite, and coated-particle fuels to support Generation IV reactor development and co-generation of electricity and hydrogen.*

Strategy

- Provide DOE with convincing leadership as the national director for Generation IV reactor materials.
- Provide the Generation IV program with new materials of interest drawn from ORNL's R&D for fusion energy and fossil energy applications.
- Collaborate with the Commissariat à l'Energie Atomique as its principal partner for development of the new materials and coated-particle fuels needed for the GFR.
- Work with Framatome in developing new heat exchanger materials for the VHTR.

Objective 3: *Maintain and upgrade the Bethel Valley hot cell complex to ensure its availability to support the R&D missions for Generation IV and AFCI and the continued secure production of isotopes.*

Strategy

- Develop and implement a strategic plan for the Bethel Valley hot cell complex that will rationalize, modernize, and consolidate the complex to support current and future missions in the most cost-effective manner.

Key Accomplishments

- Re-established capabilities to make coated-particle uranium fuels and demonstrated, in a test bed, the capability to make nonradioactive simulated fuels employing advanced coating techniques using TiN.
- Initiated modernization of the Bethel Valley hot cells.
- Initiated preparations for receipt of ^{237}Np for the future production of ^{238}Pu.
- Working with other DOE laboratories, compiled and issued the VHTR Materials Survey Report.

Objective 4: *Achieve readiness to store ^{237}Np to support future production of ^{238}Pu.*

Strategy

- In cooperation with BWXT Y-12, develop the authorization basis documents for the receipt and the safe and secure storage of ^{237}Np at the Y-12 National Security Complex.

Capabilities

ORNL capabilities include engineering cost analysis, radiation shielding, criticality safety analysis, chemical separations and processes, fission product transport phenomenon, coated-particle fuel fabrication and testing, high-temperature materials development and testing, sensors and controls technology, molten salt technologies, and isotope production. Broad expertise in safeguards and security developed at DOE's Oak Ridge facilities has been consolidated at ORNL. For Generation IV nuclear energy systems and AFCI, fundamental technologies associated with high-temperature materials, fuels, separation technologies, and cost assessment, as well as a unique clustering of key capabilities to lead or support the resolution of anticipated technical issues in such areas as sensors, extrinsic safeguards, and safety analysis, are available at ORNL.

Operational and Support Needs

ORNL's nuclear technology programs rely upon the continued operation and modernization of key experimental facilities, including

- the materials and fuels instrumented irradiation facilities at the High Flux Isotope Reactor (HFIR);
- the Melton Valley hot cell complex, especially the Irradiated Fuels Examination Laboratory;
- the Bethel Valley hot cell complex;
- the uranium-coated-particle production laboratory;
- the graphite and carbon materials laboratory; and
- the ceramics laboratories, including the High Temperature Materials Laboratory for the characterization of unirradiated materials.

Key Partnerships

- Key partnerships within the Generation IV International Forum including France and South Korea.
- Cooperative R&D agreement with USEC to develop advanced enrichment technologies using gas centrifuges.
- Other partnerships include
  - Idaho National Engineering and Environmental Laboratory on fuel development for advanced gas-cooled reactors including the VHTR,
  - Argonne National Laboratory on advanced separations technologies,
  - Sandia National Laboratories on nuclear-generated hydrogen production,
  - Framatome on the development of heat exchanger materials for the VHTR, and
  - Westinghouse on the development of the International Reactor Innovative & Secure (IRIS) advanced reactors and on the South African initiative for the development and deployment of the Pebble Bed Modular Reactor (PBMR).
- Continuing interactions with the Japan Atomic Energy Research Institute on the VHTR.

Environmental Quality

Strategic Objectives

As a result of the "Top to Bottom Review" of the Environmental Management (EM) Program conducted in 2002, the Program's goals were refocused to radically reduce the cost and time frame for cleanup of the vast environmental legacy of the cold war. Cleanup work is being prioritized to achieve accelerated reduction of risk to the public, workers, and the environment. Accordingly, EM science and technology initiatives have been streamlined to focus on fast-track implementation in line with two new thrusts: closure site support and alternatives and step improvements to high-cost, high-risk baselines.

ORNL will continue as a primary provider of science and technology underpinnings to support accelerated site closures—both locally and nationally.

1. We will provide technical assistance and short-duration technology development results to Closure Sites to enable them to meet schedule and budget constraints and control risks.
2. We will conduct research and development to evaluate alternatives to high-risk, high-cost baselines in such areas as high-level waste separations, subsurface science, in situ treatment, and advanced sensor systems for major cleanup sites.
3. We will consult with Program managers to sustain or rebuild an optimal level of core technology work and expertise to provide essential closure support in the areas of (a) robotics and remote systems and (b) characterization, sensors, and monitoring systems.
4. We will supply science and technology solutions for responsible stewards to effectively control future costs and ensure responsible management of EM sites after cleanup is completed and address sites outside EM scope that require cleanup.
5. We will contribute to an enhanced scientific basis for a permanent radioactive waste repository. The Office of Civilian Radioactive Waste Management (OCRWM) has newly stated goals for achieving better understanding of the Yucca Mountain site and improving the baseline repository system.

We will amplify our strong, multidisciplinary expertise through strategic partnerships with universities, industry, and other DOE laboratories to ensure the most advanced resources are applied to accelerate cleanup of the Department's environmental legacies.

Primary Roles in the Context of DOE Mission Objectives

Oak Ridge National Laboratory will provide scientific understanding and technological tools to help solve the Department of Energy's monumental environmental quality challenges. The priorities articulated by the Department include acceleration of site cleanup, legacy management, and safe and secure disposition of dangerous nuclear materials. Table 1 links our primary roles with the objectives of the Department's environmental quality mission. Table 2 briefly outlines the Laboratory's roles with programs or program elements.

Table 1. Roles supporting DOE mission objectives

Accelerate site cleanup	Manage the legacy	Dispose of dangerous materials
Expand support to OR Closure Program under recently signed Memorandum of Agreement to help ensure world-class solutions are brought to bear on local problems.	Support the Office of Science in negotiation of conditions for and definition of liabilities and costs inherent in assumption of the stewardship role for closed ORNL facilities.	Continue depressurization of NaF cylinders and support for conversion of UF_6 from the Molten Salt Reactor Experiment.
Provide ecological monitoring and assessments to support annual site environmental reports and remediation effectiveness evaluations.	Provide innovative science and technology tools for future long-term stewards concerning monitoring, surveillance and maintenance, institutional controls, cleanup of future sites, re-remediation, and site re-evaluation to reduce costs of post-cleanup activities.	Support the Office of Civilian Radioactive Waste Management in its new science program to bolster Yucca Mountain repository license application.
Expand participation in multi-institutional support for closure of Ohio sites, including Fernald's silos, problem wastes, underground contaminants, and "closure enablement" to ensure schedules are met within budgets.		Provide support for radioactive waste packaging, storage, and transportation via the National Transportation Research Center and the Nuclear Criticality Safety Program.
Apply broadly based expertise to support development of alternatives for legacy waste and site and facility cleanup at Savannah River, Hanford, and Idaho.		Provide scientific expertise and technical support to enable and improve the Department's plans to convert depleted uranium hexafluoride tails to a stable oxide and disposition the conversion products.

Objectives and Strategies

Objective 1: *Provide technical assistance and short-duration technology development results to Closure Sites to enable them to meet schedule and budget parameters and control risks.*

Strategy

- Build on the recently signed Memorandum of Understanding with Oak Ridge's cleanup contractor to provide technical support and identification and / or development of cost-effective solutions in the areas of robotics / remote systems, characterization / monitoring, and environmental remediation.
- Expand successful technical support and technology testing roles in retrieval, packaging, and transportation of silo wastes at Fernald to similar roles at additional closure sites.
- Participate with other institutions on multi-disciplinary teams to provide direct, short-term expertise and conduct focused technology development and demonstration projects.

Objective 2: *Supply scientific rationale and technical resources to support consideration of alternatives and step improvements to sites' baseline closure plans.*

Table 2. Program roles

Program area	ORNL role
Closure Site Support	Technical assistance and/or demonstration of new technologies for Ohio, Rocky Flats, and Oak Ridge.
Alternatives to Baseline	Development and demonstration of superior, alternative approaches and provision of scientific basis for defensible decisions for sites with major mortgages.
Technical Solutions Assistance	Participation on technical teams to bring the ultimate science and technology to bear on intractable or unwieldy site problems.
Core Technologies	Research and development in cutting-edge robotics and remotely operated systems; chemical separations and processing; subsurface science; and characterization, monitoring, and sensor systems.
Legacy Management	Science, technology, and technical assistance to ensure responsible, cost-effective stewardship strategies and earn public and regulatory support.
Civilian Radioactive Waste	Research to better understand the repository site and improve the initial licensing baseline.
Transportation	Application of National Transportation Program logistics evaluation tool, advanced packaging technologies, and regulatory compliance analysis to DOE and civilian applications.
Depleted Uranium	Coordination of technical support for the DUF_6 conversion project and international research and development related to safe disposition and beneficial reuse of DUF_6.
Nuclear Criticality Safety	Performance of neutron cross section measurements; data analysis, testing, and maintenance; provision of user assistance in the SCALE/KENO code system; and conduct of additional tasks to improve margins of safety and operational efficiencies.
ORO Cleanup Support	Depressurization and subsequent storage and monitoring of NaF traps and possible conversion of UF_6 therein; scientific and technical support for groundwater and ecological strategies and other cleanup decisions and actions; technology development to provide superior and/or less costly solutions.

Strategy

- Continue/expand targeted R&D in support of Savannah River's salt waste treatment project.
- Respond to calls for proposals extended by additional high-impact alternatives projects.

Objective 3: *Sustain or rebuild "core technology" R&D in robotic and remote systems and characterization, sensing, and monitoring systems.*

Strategy

- Prepare proposals for new initiatives in consultation with national program management.

Objective 4: *Expand long-term stewardship science and technology program elements to support the needs of the new Office of Legacy Management and landlords of sites with ongoing missions.*

Strategy

- Support future stewards of closed legacy sites in assessing their liabilities and science and technology needs.
- Integrate ORNL strengths in institutional science, sensing / monitoring systems, advanced computing, subsurface fate and transport, and ecological assessment to formulate proposals to address these site stewardship needs.
- Focus on the Oak Ridge Reservation as the first of the "complex," continuing mission sites requiring long-term stewardship.

Objective 5: *Rebuild ORNL R&D supporting OCRWM's goals of achieving better understanding of the Yucca Mountain site and improving the baseline repository system.*

Strategy

- Engage OCRWM and Yucca Mountain Project staff, contractors, and other relevant organizations to elucidate specific research targets.
- Coordinate interdisciplinary efforts to develop proposals in targeted areas, using ORNL capabilities in spent nuclear fuel packaging and transportation analysis, advanced materials research, depleted uranium uses research, radiation shielding, nuclear criticality analysis, and geosciences expertise.

Recent Accomplishments

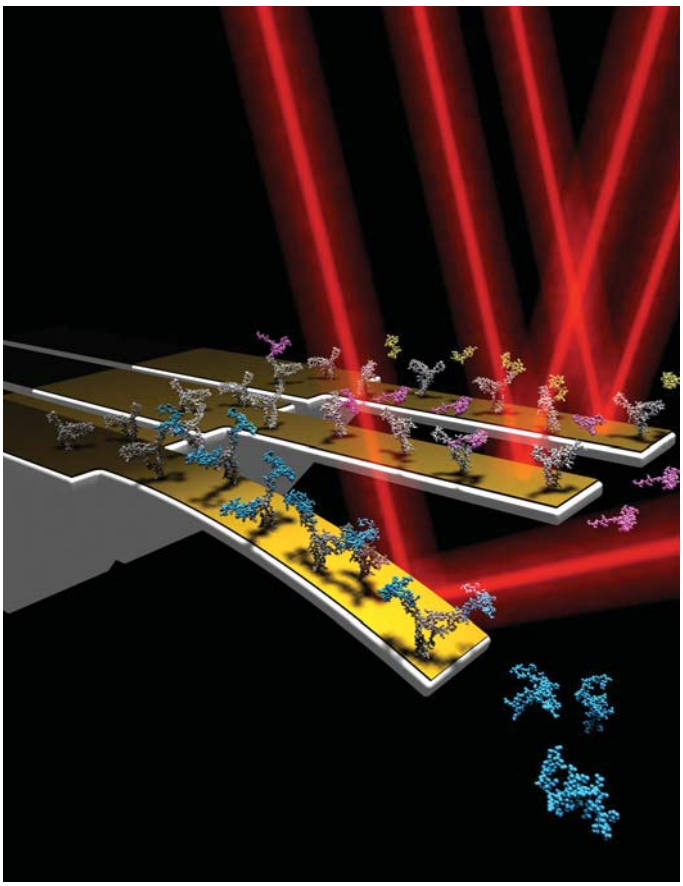
- The Caustic-Side Solvent Extraction (CSSX) process developed and patented at ORNL was selected as the baseline cesium-removal technology for Savannah River's high-level salt waste (2001).
- About ten NaF traps containing adsorbed $^{233}UF_6$ from the Molten Salt Reactor Experiment (MSRE) have been depressurized inside Building 4501's Hot Cell D, significantly reducing a vulnerability (2003).
- Adaptation of the microcantilever sensor for real-time monitoring of mercury in surface water at Y-12 is being funded by the Oak Ridge cleanup program. The research underpinning this technology was supported by the Environmental Management Science Program and others (2003).
- A memorandum of agreement between Bechtel Jacobs Company and UT-Battelle was established to foster collaboration and bring to bear the best available scientific knowledge, technology, and expertise in the planning and execution of the Oak Ridge cleanup program (2003).

Capabilities

With arguably the most diverse research portfolio in the national laboratory system, ORNL is well positioned to provide a full range of innovative science and technology solutions to serve the Department's environmental quality mission. Expertise spans the gamut of radiochemical separations; process engineering; robotics and remote systems; mass spectrometry; laser spectroscopy; nuclear materials; nuclear and atomic physics; sensors, electronics, and signal analysis; modeling and simulation; terascale computing; biogeochemistry; environmental biotechnology; environmental chemistry; ecological risk assessment; geosciences; hydrology; environmental assessment; economics and social science; and policy and regulatory analysis. Specialized facilities include hot cells, Oak Ridge Electron Linear Accelerator, robotics high bay facility, tanks cold test facility, Oak Ridge Environmental Research Park, Natural and Accelerated Bioremediation Research Program Field Research Center, and aquatics ecology laboratory.

Operational and Support Needs

Support for the Robotics High Bay is needed to sustain capabilities for the robotics and remote systems Core Technology Area. Support for the Tanks Cold Test Facility is needed to serve EM tank waste retrieval needs. Maintenance of 4501 Hot Cell D is required for continued support of the Molten Salt Reactor Experiment (MSRE) UF_6 cylinder depressurization and conversion. Continued



Selection of a microcantilever coating that specifically targets the contaminant of concern enables highly selective and sensitive contaminant detection. Microcantilever technology is being adapted for detection of mercury in surface water at Y-12 and is widely applicable to other contaminants and media.

National Nuclear Security Administration (NNSA) funding (responsible by agreement) is needed for maintaining the National Criticality Safety Program (NCSP) infrastructure capability that serves EM.

Programmatic coordination is needed to expand technical support roles, recruit multi-disciplinary teams, respond to calls for proposals, and participate on the Environmental Laboratory Consortium (ELC). A coordinator (SC) is needed for (1) transition of long-term stewardship planning and implementation responsibilities for ORNL from EM to SC and (2) participation in cleanup decisions that impact stewardship requirements. A programmatic contact is needed to implement the strategy supporting OCRWM goals by coordinating the small elements of work performed in a number of groups across ORNL, engaging OCRWM, transferring information, and preparing proposal(s).

Key Partnerships

ORNL's diverse and specialized capabilities are further leveraged and applied through far-reaching partnerships with universities, private and public institutions, industries, and other national laboratories. Of particular value to the environmental quality mission are collaborations through the following entities.

- Nuclear Criticality Safety Program—established in response to Defense Nuclear Facilities Safety Board (DNFSB) Recommendation 97-2 and managed by NNSA. Responsible for maintaining nuclear criticality infrastructure and capabilities to serve site needs.
- National Transportation Research Center—a research alliance among ORNL, the University of Tennessee (UT), and the Development Corporation of Knox County. Serves EM needs related to hazardous materials packaging, transportation logistics, and regulatory compliance analysis.
- Joint Institute for Energy and Environment—a partnership between UT, TVA, and ORNL to collaboratively engage expertise and facilities in research related to energy, environment, and economics.
- Environmental Laboratories Consortium—a partnership among major DOE laboratories to identify and integrate the best technical resources for solving specific site cleanup issues, network with other relevant offices and agencies, leverage Office of Science activities, and anticipate future EM science and technology needs.
- Bechtel Technology Panel—a team of representatives from Bechtel-managed cleanup sites seeking to optimize S&T communication and utilize best practices and technologies.

Homeland Security

Strategic Objectives

In October 2001, Secretary Abraham issued explicit program guidance to the DOE's Leadership Council on the mission and priorities of the department. The secretary declared National Security to be the department's single overarching mission. Almost 2 years later, the mission remains the same. However, with the advent of the Department of Homeland Security (DHS) in 2003, the focus is clearer. ORNL's role in homeland security is to work collaboratively with other DOE national laboratories to provide the science, technology, and expertise required to detect, prepare for, prevent, protect against, respond to, and recover from terrorist attacks within the United States.

ORNL intends to play a major role in securing the American homeland. We have established eight strategic objectives for our Homeland Security Program.

1. Become the acknowledged experts in the area of radiation dispersal devices (RDDs) based on our 60 years of experience in producing and distributing what are considered to be RDD-usable radioisotopes. We will supply ORNL's, unique facilities and experience to support all aspects of RDDs, including detection, nonexplosive dispersal science, attribution, and radioisotope source hardening.
2. Be at the forefront of developing and applying technologies in the detection and mitigation of chemical and biological threats. We will develop advanced sensors, sensor systems, and diagnostics of chemical and biological threats, as well as apply our rich mammalian genetics expertise to understanding host/pathogen interactions.
3. Make significant contributions to protecting the nation's energy infrastructure. We will supply key capabilities at the National Transportation Research Center, as well as decades of experience in energy-related infrastructure assurance, to advanced tagging and tracking, inspection technologies, modeling and simulations of vulnerabilities, and mitigation of consequences.
4. Serve as a premier provider of information management and assessment tools, including the deployment of the SensorNet architecture, to collect, analyze, and disseminate information to responders. Using various ORNL-developed tools such as HPAC, VIPAR, LANDSCAN, and HYTRAS, the Laboratory will support infrastructure protection initiatives on a nationwide scale.
5. Develop technology and systems that improve the effectiveness of emergency response to terrorist attacks. By applying several decades of experience gained from assisting the Federal Emergency Management Agency (FEMA), which is now part of DHS, we will support emergency operations ranging from response to consequence management, including decontamination.
6. Become the premier center for DHS science and technology in the southeast region through the establishment of outreach programs and cooperative relationships that provide technical support to state and local governments, industry, and universities.
7. Assist DHS by providing technical staff to support the mission of its Science and Technology Directorate in such areas as radiation countermeasures and international cooperation.
8. Build a National Security Science and Technology Facility. This building will provide the space and equipment needed to conduct ORNL's classified research activities for DHS.

We will make extensive use of current technologies and leverage programs sponsored by NNSA, the Department of Defense, the Office of Science, and others to provide advanced technological solutions to homeland security concerns. The Homeland Security program is designed to encourage interaction and promote collaborative work with other federal laboratories, universities, and industry.

Primary Roles in the Context of DHS Mission Objectives

Secretary Abraham and Secretary Ridge have executed a Memorandum of Agreement fulfilling the legislative intent of establishing DOE laboratories as a resource for DHS. As part of this arrangement, ORNL has been designated as a homeland security national laboratory (HSNL). Consequently, ORNL support for DHS homeland security mission fits within the prescribed missions of the national laboratories and is complementary to the national security and nonproliferation missions of DOE.

The Directorate of Science and Technology of DHS is a unique organization within the federal government and will oversee the vast majority of technological research and development supported by DHS, including those for other directorates as well as end users (e.g., first responders). Initial funding was largely provided by existing DOE programs in the NNSA Office of Nonproliferation Research and Engineering (NA-22), which became DHS programs on March 1. These programs focused on biological, chemical, and radiological/nuclear countermeasures. Because of their long-standing and extensive experience in supporting programs in biological, chemical, and nuclear science, the DOE laboratories will play a significant role in the DHS Directorate of Science and Technology.

ORNL will contribute to the following DHS directorates:

DHS Directorate	ORNL role
Science and Technology	
Rad/Nuc countermeasures	Leadership in RDD countermeasures; support to Improvised Nuclear Devices (IND) countermeasures
Chemical countermeasures	Major contributor in chemical agent detection
Biological countermeasures	Team member in biological agent detection, leader in mammalian genetics host/pathogen interaction
Threat and vulnerability	Major contributor in Geographic Information Systems (GIS), data management, intelligent agents
High explosive countermeasures	Major contributor in explosives detection and blast hardening
Critical infrastructure protection	Major contributor in physical security and energy and transportation security
Border and Transportation Security	Work with U.S. Customs and other border and transportation security agencies in support of the weapons-of-mass-destruction interdiction
Emergency Preparedness and Response	Work with FEMA to support emergency response planning and consequence management
Information Analysis and Infrastructure	Development of program to support information assurance and cyber security with existing ORNL capabilities

ORNL is helping to develop program planning documents for key S&T focus areas, including biological countermeasures, radiological / nuclear countermeasures, and infrastructure protection. Upon completion of thee documents, HSNL teams will be selected and given responsibility for determining how the plans are to be executed. ORNL expects to play a significant role as a leader or team contributor in such areas as radiological / nuclear countermeasures, chemical countermeasures, sensor architecture, and networking. Program efforts are expected to begin late in FY 2003 and will continue as delineated in the program planning documents and subsequent documents that describe how these plans are to be executed.

Objectives and Strategies

Objective 1: *Develop capability to characterize RDD events and the technology to intercept and attribute these RDDs while simultaneously hardening/protecting ORNL-produced isotopes.*

Strategy

- Combine the capabilities created by multisponsored programs into a coherent RDD countermeasure program for DHS.

Objective 2: *Develop advanced sensors, sensor systems, and other diagnostics of chemical and biological threats; use ORNL's mouse genetics expertise to understand host/pathogen interactions.*

Strategy

- Grow ORNL's leadership position in next-generation mass spectrometry systems.
- Leverage substantial programs with Department of Defense (DOD) Chemical, Biological, Radiological, and Nuclear (CBRN) sponsors for DHS applications.
- Promote the study of complex pathogen / host interactions by providing targeted mouse strains to national laboratories and other institutions studying pathogens.

Objective 3: *Position SensorNet to become the preferred infrastructure for the widespread deployment of CBRN sensors and detectors.*

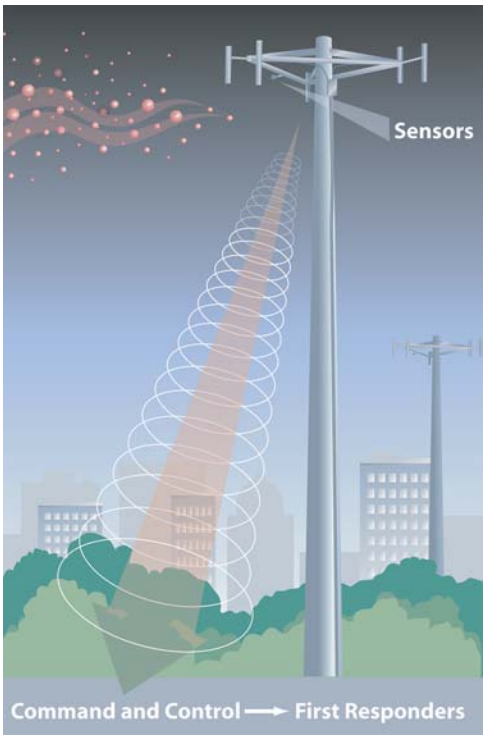
Strategy

- Continue demonstrations of sensor networking for multiple customers.
- Grow ORNL's contributions and roles in integrated sensor demonstrations and in emergency response exercises sponsored by DHS and other federal, state, and local agencies.

Objective 4: *Develop technology and systems that improve the effectiveness of emergency response to terrorist attacks.*

Strategy

- Leverage ongoing work for FEMA and the Office of Domestic Preparedness (ODP) on emergency response to natural disasters to include response to all homeland security emergencies.



SensorNet, a homeland security project at ORNL, would provide a quick-response network in the event of a terrorist attack involving chemical, biological, or radiological agents, including so-called "dirty bombs."

Objective 5: *Serve as a regional center of excellence through the establishment of outreach programs to state and local governments, industry, and universities.*

Strategy

- Develop relationships throughout the Southeast with state and local governments, industry, and universities and serve as the science and technology interface for DHS to regional stakeholders.

Capabilities

As DOE's largest multiprogram science laboratory, ORNL has a number of unique facilities and capabilities that can be used to support DHS missions:

- Four decades of experience with active neutron-based interrogation for highly enriched uranium (HEU).
- Six decades of experience in the development and fabrication of radioactive sources, along with associated specialty handling facilities—ten hot cells for analysis and processing of highly radioactive materials.
- Radiochemical Engineering Development Center (REDC)—The REDC produces transuranium elements as part of the heavy-element research program. Targets for irradiation are designed and fabricated at the REDC. After irradiation at the High Flux Isotope Reactor, the targets are chemically processed at the REDC to extract the desired elements.
- High Flux Isotope Reactor (HFIR)—The world's highest flux research reactor and associated instruments for neutron imaging of materials and biological samples, isotope production, and irradiation experiments.
- The Californium User Facility—Processes and encapsulates the national supply of ^{252}Cf, produced at the neighboring HFIR, and stores ^{252}Cf neutron sources for the Californium Industrial, University, and Medical Loan Program.
- Oak Ridge Electron Linear Accelerator (ORELA)—used to determine nuclear cross sections of materials.
- National and international leadership in development of standards and environmental testing for radiation detection devices.
- Six decades of experience in developing advanced mass spectrometric techniques that can provide confident, fast, ultratrace chemical analysis of nuclear materials, explosives, and chemical and biological agents. Developed Chemical Biological Mass Spectrometer, only field-deployable device capable of detecting both chemical and biological agents in near real time, with supporting facility capable of handling trace chemical and biological agents.
- Bio Safety Level 3–certified bio-defense laboratory—Supports research on advanced sensors and detectors for biological and chemical weapons.
- Mouse vivarium—Facility for genetics analysis including well-characterized phenotypic mouse populations, gene sequencing capability, and biomedical imaging.
- Numerous information management tools, developed at ORNL and in use by the military, provide rapid modeling and assessment of data to assist decision makers and national leader in information assurance vulnerability assessments and cybersecurity.
- National Transportation Research Center—Comprehensive facility for developing technologies to support protection of the nation's transportation infrastructure.

Operational and Support Needs

The National Security Science and Technology Facility is urgently needed to support homeland security mission objectives, along with the installation of and access to SIPRNet. ORNL requires comprehensive space for handling classified materials and projects and conference space and training up to the Top Secret level. The current classified space will soon be inadequate to support our national and homeland security programs, and continuing to use classified areas at Y-12 is not practical.

Key Partnerships

Designated Homeland Security National Laboratories (HSNLs) (including ORNL, Los Alamos National Laboratory, Sandia National Laboratories, Lawrence Livermore National Laboratory, and Pacific Northwest National Laboratory) work collaboratively in the execution of the entire DHS S&T portfolio. In addition, as the only HSNL in the southeast region, ORNL is expected to develop partnerships with other DOE and NNSA assets, including the Y-12 National Security Complex and the Savannah River Technology Center, with whom ORNL already collaborates.

Partnerships will also be developed with end users in the region, principally through DHS departments established as part of the state governments (or similar groups that may include emergency response and public safety). ORNL is already working with the Tennessee Departments of Homeland Security, Transportation, and Public Safety and will expand its work to include other states in the region. An understanding of local and regional requirements is crucial in developing an effective S&T portfolio, and ORNL is expected to play a key role in working with cognizant local personnel.

Key partnerships are being established and maintained with universities. For example, ORNL has already established a relationship with the University of Tennessee (UT) Center for Homeland Security. ORNL is also teaming with Duke University, Vanderbilt University, University of North Carolina–Chapel Hill, Emory University, University of Florida, and University of Alabama–Birmingham to establish an NIH Regional Center of Excellence in Biodefense and Emerging Infections. A consortium of UT–Knoxville, UT–Martin, UT–Memphis College of Medicine, Vanderbilt University, and ORNL is proposing to work with the Health Resources and Services Administration of the Department of Health and Human Services on bioterrorism training and curriculum development. This same consortium is also working with the Federation of American Scientists to develop a certified and accredited curriculum for bioterrorism response that uses advanced information tools for learning and incorporates the latest research on cognitive science.

Partnerships will also be developed with the private sector. It is intended that all resulting technologies be used by local, state, and federal personnel involved in counterterrorism interdiction and response. Consequently, it is important to establish a robust technology transfer program that will make sure technologies are rapidly transitioned to companies that can make the devices for the end users.

Finally, ORNL will place a representative on the inter-laboratory Technology Transfer Working Group to advise senior S&T Directorate managers concerning policy issues and recommendations for technology transfer.

Defense Nuclear Nonproliferation

Strategic Objectives

Reducing the global danger from proliferation of weapons of mass destruction (WMD) is a high priority for the U.S. Government and a key strategy of DOE and the National Nuclear Security Administration (NNSA). Long-standing concerns regarding the potential misuse of nuclear energy have been intensified by new threats posed by malevolent use of scientific knowledge of biological and chemical systems as well as their weaponization and delivery. DOE/NNSA is the U.S. leader in nuclear threat reduction and an important technical contributor in the area of proliferation prevention associated with other WMD.

ORNL is positioned to play a major role in this threat reduction strategy by application of its knowledge and experience in nuclear, chemical, and biological sciences. The results will include analyses, instrument development and engineering, implementation of government policy initiatives for monitoring, countering terrorist access, nuclear safety and security improvements, and elimination of WMD materials. In consultation with the NNSA, we have established four strategic performance goals for the threat reduction program:

1. Enhance the capability to detect WMD, including nuclear, chemical, and biological systems.
2. Prevent and reverse proliferation of WMD.
3. Protect or eliminate weapons and weapons-usable nuclear materials or infrastructure and redirect excess foreign weapons expertise to civilian enterprises.
4. Reduce the risk of accidents in nuclear fuel cycle facilities worldwide.

Use of neutron capture gamma spectrometry technology developed at ORNL to obtain data for strategic arms reduction assessments.

Primary Roles in the Context of DOE Mission Objectives

ORNL receives direction from the NNSA, other components of DOE, and other federal agencies working through DOE to develop and implement science- and technology-based measures aimed at reducing threats—internal and external—to the United States from WMD. The primary focus is to reduce the proliferation of nuclear materials and weapons. ORNL's expertise in biological, medical, chemical, and metallurgical sciences is becoming increasingly critical for threat reduction in the areas of chemical and biological weapons and missile delivery systems. ORNL's primary missions are encompassed in the following NNSA Defense Nuclear Nonproliferation programs: Nonproliferation and Verification Research and Development; International Nuclear Safety and Cooperation, Highly Enriched Uranium (HEU) Transparency Implementation, Nonproliferation and International Security, International Nuclear Materials Protection and Cooperation, and Fissile Materials Disposition.

Nonproliferation and Verification Research and Development

This program supports objectives in arms control; treaty verification; counterproliferation; and assessments for the broader nonproliferation, intelligence, homeland security, and law enforcement communities outside NNSA. The program promotes a technology-based approach to the reduction of threats to national security and world stability posed by nuclear, chemical, and biological weapons proliferation and illicit materials trafficking and also assists in fulfilling U.S. commitments for treaty monitoring. ORNL is developing advanced materials for use in radiation detection, developing miniature versions of conventional chemical laboratory instruments for field measurements, developing techniques for ultratrace analysis samples, and applying decades of experience in reactor-related work to the field of attribution. As part of our work on emerging technologies applicable to nonproliferation problems, an exploratory research and development program is under way that supports initial development of promising technologies.

Arms Control and Disarmament

The Arms Control Program is focused on the safe and secure storage of materials that result from the dismantlement of nuclear weapons in the Russian Federation. Agreements between the Russian Federation and the United States to reduce their nuclear arsenals have led to renewed levels of cooperation between U.S. and Russian laboratories. Cooperative counterterrorism initiatives are being formulated under the existing U.S.–Russian Warhead Safety and Security Exchange Agreement. With regard to former Soviet states, the primary focus is the removal of potential materials for nuclear weapons or radiological dispersal to more secure locations.

Export Control

The established Export Control (EC) program focuses on technical support for national and international export control as a key part of U.S. national security and foreign policy. Primary emphasis remains on nuclear and nuclear dual-use equipment, materials, and technologies. However, the technical base of the Oak Ridge Complex is also being applied to establish technical definition and obtain advice for national and multinational actions pertaining to risks from all WMD and their delivery means. ORNL expertise has been sought to identify high-proliferation-risk equipment being removed in the dismantlement of the DOE and NNSA nuclear weapons and other sensitive nuclear process facilities to avoid inadvertent release to malevolent parties. To promote sharing of experiences, the EC program conducts training (at DOE/NNSA direction) for personnel from across the country and from friendly foreign governments.

Highly Enriched Uranium Transparency

The Transparency Program supports the Highly Enriched Purchase Agreement between the United States and the Russian Federation. The agreement currently calls for the United States to purchase 500 metric tons (MT) of HEU [in the form of low-enriched uranium (LEU)] from dismantled nuclear weapons. These purchases span a 20-year period, with the product being used to fuel light-water reactors in the United States. By the end of CY 2002, approximately 170 MT had been converted and shipped to the United States. Through on-site monitoring, data exchanges, and the use of continuous nonintrusive monitoring equipment, the program ensures that each side is abiding by the terms of the agreement and that the U.S. nonproliferation goals are met.

International Safeguards

The International Safeguards (IS) program supports U.S. initiatives to increase the effectiveness and efficiency of the International Atomic Energy Agency (IAEA), which provides the international community with independent assurances that countries are in compliance with their own nonproliferation commitments. ORNL (1) provides technical expertise in implementing IS at facilities in the United States; (2) supports DOE's cooperation agreements with key IS organizations; and (3) develops, tests, and evaluates strengthened safeguards measures to be applied globally by the IAEA. Additional technical support is provided directly to the IAEA via the U.S. Program for Technical Assistance to IAEA Safeguards, which is funded by the U.S. Department of State.

Materials Protection, Control, and Accounting (MPC&A)

This program works with Russian facilities to secure weapons-usable nuclear materials, help improve safeguards and security systems at the facilities, and improve nuclear material accounting systems. ORNL provides technical support in an effort to supply the Russian nuclear complex with safe and secure transportation, both truck and rail, for weapons-usable nuclear materials and nuclear weapons. ORNL provides support to the Material Consolidation and Conversion project by monitoring the down-blending of HEU to LEU and serves as project leads to oversee the physical protection and material control and accounting upgrades at several Russian facilities. The MPC&A program is considered the "first line of defense" in preventing the inadvertent release of Russian weapons and weapons-usable nuclear material to rogue nations and terrorist groups as well as addresses other nations that have similar at-risk materials.

Second Line of Defense

Border security and interdiction of illicit nuclear and radioactive materials in transit across international boundaries are the focus of the Second Line of Defense. Begun as a joint activity with the Russian Federation in 1998, the program now addresses the global character of terrorism threats that might involve nuclear or radioactive materials. ORNL contributes its expertise in nuclear and radioactive materials detection and its experience in the training of border security specialists. Significant expansion of the program will focus on U.S. border security and the off-shore screening of cargoes destined for U.S. seaports and airports.

Plutonium Disposition in the Russian Federation and the United States

This program supports the 1998 and 2000 United States and Russian agreements for the parallel disposition of weapons plutonium that is no longer needed for defense purposes. A dual-option program was initiated in 1998 to immobilize part of the plutonium inventory and to burn part of this inventory as reactor fuel. In 2001 the immobilization option was dropped in order to concentrate assets on the reactor option.

Russian Program—This program focuses on the implementation of the 2000 agreement via the construction of Russian fuel fabrication facilities and the modification of Russian nuclear power plants to carry out the plutonium disposition mission. The major Oak Ridge roles include management, technology, and contracting support for Russian (1) fuel design, qualification, and fabrication and (2) reactor design, safety, and modifications. ORNL also supports the program in the development of the Russian nuclear safety regulatory infrastructure, the technology for conversion of plutonium metal into oxide, the development of a monitoring and inspection regime, and cost analyses.

U.S. Program—An implementation consortium was contracted by DOE in 1999 to build and operate a fabrication facility to process the powdered plutonium feed material into reactor fuel assemblies and provide for their disposition in U.S. commercial reactors. The major ORNL roles in this part of the program include support for DOE in (1) fuel design and qualification; (2) fuel fabrication facility design and licensing; (3) reactor modification design, safety, and licensing; and (4) fresh fuel packaging and transportation. ORNL also supports DOE in the nuclear safety regulatory infrastructure, the technology for conversion of plutonium metal into oxide, removal of impurities in plutonium oxide feed, and economic analyses of various options for these tasks.

ORNL supports eight major objectives that fall within four program offices of the NNSA Office of Defense Nonproliferation.

Subprogram	ORNL Roles
Nonproliferation and Verification R&D (NA-22)	Development, design and construction of sensors
Arms Control and Disarmament (NA-24)	Cooperative dismantlement of nuclear weapons; implementation of regional threat reduction initiatives
Export Control (NA-24)	National and multilateral controls for nuclear, chemical, biological, and missile technologies, materials, and equipment
Transparency (NA-24)	Cooperative monitoring of uranium removed from nuclear weapons for down-blending for civil use
International Safeguards (NA-24)	Technical support for effective international safeguards and for voluntary offer inspections in the United States
Materials Protection, Control and Accounting (NA-25)	Security and accountancy for foreign nuclear and radioactive source materials security in civilian and military custody
Second Line of Defense (NA-25)	Border controls for prevention and interdiction of nuclear and radioactive materials smuggling
Plutonium Disposition in Russia and the United States (NA-26)	Disposition in civil power reactors of plutonium removed from weapons

Objectives and Strategies

In order to support the threat reduction mission of DOE/NNSA and the role of ORNL described above, we plan to support initiatives of the NNSA in responding to serious national security impacts from negative developments in the proliferation of nuclear, biological, and chemical weapons capabilities. Listed are three areas of program development in support of the NNSA threat reduction objective.

Objective 1: *Expand ORNL's role in the development, design, and implementation of technological applications for defense nuclear nonproliferation.*

Strategy

- Maintain current awareness of NNSA and other national requirements.
- Broadly engage research and development staff to explore new and creative solutions and apply cutting-edge technologies.
- Ensure that the DOE Office of Science is kept informed of ideas for fundamental research that have potential application to national security.

Objective 2: *Build partnerships between ORNL, other national laboratories, and private-sector applied science entities to meet critical nonproliferation needs.*

Strategy

- Exploit opportunities afforded by the Office of Science to identify multidisciplinary strengths of national laboratories.
- Organize proposals involving skill sets of multiple national laboratories.
- Continue partnering with the Oak Ridge Y-12 National Security Complex.

Objective 3: *Maintain and nurture strong science and technology skills of ORNL personnel relevant to nonproliferation.*

Strategy

- Provide opportunities for R&D staff to learn details of national security technology needs, including national security classified information.
- Provide opportunities for newly hired staff to study technical details of past projects and innovations from programs and processes no longer active in Oak Ridge.
- Provide secure workplace with technology demonstration and testing.

Key Accomplishments

- Partnering with the Y-12 National Security Complex for Russian Transition Initiatives in closed nuclear cities.
- Securing and removing at-risk nuclear materials in Yugoslavia.
- Threat reduction projects in Russia involving Radiological Dispersal Device materials.
- Border security training for interdiction of nuclear materials and nuclear dual-use goods.
- Recovery of nuclear power reactor components after loss of export control.
- Nuclear dual-use goods recognition training for foreign export control officials.
- Nuclear materials protection cooperation with Strategic Rocket Forces of the Russian Federation.
- 100th International Atomic Energy Agency Inspection of weapons uranium at the Y-12 National Security Complex, May 2003.
- Inspection of nuclear and suspect facilities in Iraq since 1991.
- Plutonium disposition fuel prototype irradiation testing successful.
- Nuclear materials transit security accomplishments in Russian Federation.
- Recovery and rendering safe potential Radiological Dispersal materials from a war zone.
- Implementation of transparency monitoring during 2002 for blend-down of 30 metric tons, about 1200 weapons quantities, of Russian uranium.
- Completion of design basis for Plutonium Mixed Oxide Fuel Plant and initiation of Russian acceptance review.
- Completion of plan and cost estimate for replacement of Russian Breeder Reactor BN-600 radial blanket.
- Support to International Safeguards inspections in South Africa for former nuclear weapons materials production complex.
- Radiological dispersal risk assessments in former Soviet Union new independent states.
- Radiation monitoring and gamma spectrometry cooperation with Russian Customs Committee.
- Technical support to U.S. export decisions for nuclear, biological, chemical, and missile technologies.

Capabilities

ORNL capabilities for threat reduction reside primarily in its experienced multidisciplinary workforce. We draw on the Laboratory's great breadth and depth in nuclear science and technology, establishing this research base in materials science, chemistry, and the life sciences, not to mention expertise and information analysis capabilities. Combining a solid appreciation for national security policies and objectives with world-class science and engineering experience provides a fertile ground for reliable technical assessments of proliferation prospects and consequences, as well as technical means for detection and characterization of threats.

Operational and Support Needs

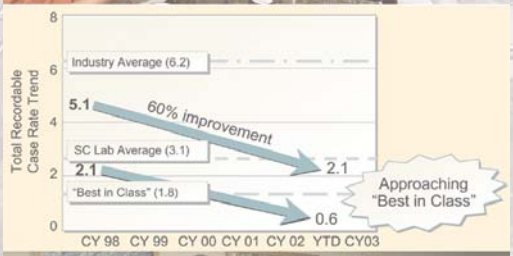
Continued support is needed for adequate work spaces on the main campus of ORNL, including secure work spaces that combine facilities for training Government officials as well as national security equipment testing and demonstration.

Key Partnerships

ORNL will continue efforts to identify complementary activities with other national laboratories such as Pacific Northwest National Laboratory and Brookhaven National Laboratory, with educational institutions such as the University of Tennessee, and with private science and technology foundations and businesses in the East Tennessee Technology Corridor and nationally.

Oak Ridge National Laboratory

Management Systems



- Environment, Safety, and Health
- Human Capital
- Safeguards and Security
- Financial Management
- Information Technology Management
- Site and Facilities Management
- Technology Transfer and Economic Development
- Public Awareness and Community Outreach
- Science Education

Summary

Over the last three years, ORNL has been engaged in an effort to improve our facilities and infrastructure and strengthen operational performance. In addition to our highly visible facilities revitalization initiative, we have undertaken substantial efforts to improve safety, reduce a substantial legacy materials burden, improve the effectiveness of support to research, and reduce cost. We have made significant progress in all of these areas, but substantial challenges remain.

To enable these and other improvements, we have organized and now manage our operational activities and budgets around a set of cross-functional management systems. In keeping with our philosophy of simultaneous excellence in research, laboratory operations, and community service, we are designing each management system to effectively enable research while ensuring operational compliance and protecting DOE assets as appropriate to the scope of that system. Our efforts to strengthen management system performance are evaluated and informed by a vigorous self-assessment process, often including the use of external review or certification.

In this portion of the Institutional Plan, we present our strategies for the continued enhancement of our operational performance through the ongoing development and maturation of our management systems. The discussion is organized by broad functional area and represents a summary of more detailed plans that we prepare at the level of individual management systems. In each functional area we discuss the primary outcomes and associated performance measures that we expect; an identification of opportunities to improve effectiveness and impact based on our self-assessments, DOE guidance, and other performance data; our objectives and strategies for achieving the identified improvements; and a brief summary of progress and recent accomplishments.

Environment, Safety, and Health

Key Outcomes and Associated Performance Measures

The Environment, Safety, and Health (ES&H) system is designed to

- enable ORNL science and technology R&D through the creation of a safe workplace for a cadre of trained workers,
- protect the public and environment from unacceptable risk, and
- ensure efficient compliance with regulations and other operational requirements through the creation of coherent instructions and tools.

The outcomes we expect for our ES&H system include the following:

- Achieve "Best in Class" worker safety performance, as measured by standard safety and health metrics and composite indicators such as lost workday case rate and success in maintaining radiation exposure as low as reasonably achievable (ALARA).
- Eliminate environmental vulnerabilities and legacy materials, as measured by disposition of legacy materials and by demolition of excess facilities.
- Integrate pollution prevention into planning as measured by the reduced generation of certain pollutants.
- Enable world-class research by developing efficient, cost-effective, user-friendly ES&H systems and services, as measured by benchmarking the ES&H management systems of other DOE laboratories and soliciting feedback from researchers.
- Ensure compliance with all applicable rules and regulations, as measured by a robust, mature self-assessment system; independent oversight; and external rules.
- Move from an expert-based approach to a standards-based approach to ES&H, as measured by progress towards completion of a standards-based management system and increased maturity of that system.

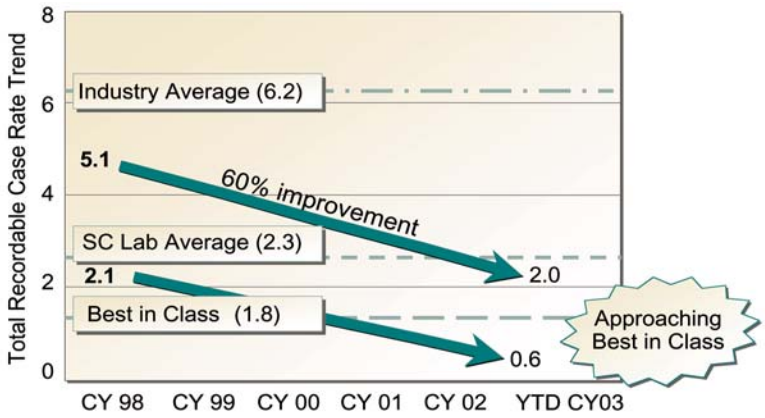
The ORNL ES&H program is implemented through five management systems.

Function	Role
Environmental Management	Assess and control the impact of UT-Battelle activities and facilities on the environment to ensure that UT-Battelle is in compliance with environmental laws and regulations.
Nuclear and Facility Safety	Reduce the probability and consequences of events resulting from both routine operations and operational upsets in ORNL facilities through analysis of hazards and risks and development and implementation of controls.
Radiological Protection	Maintain exposures to radiation and radioactive materials at ALARA levels; protect facilities and equipment from contamination with radioactive materials; and ensure compliance with regulatory and contractual requirements.
Training and Qualification	Provide staff with the knowledge and skills necessary to perform their jobs safely, effectively, and efficiently.
Worker Safety and Health	Ensure a safe and healthy workplace for all employees, visitors, vendors, and subcontractors of the Laboratory through the identification, evaluation, and control of hazards in the workplace and by providing assistance to those conducting work to enable efficient compliance with regulations.

Situation Assessment

ORNL combines the results of our self-assessment program, UT-Battelle oversight activities, and DOE and other external audits and reviews to determine the effectiveness of our ES&H systems and tools. Rigorous and comprehensive self-assessment with line management leadership and involvement is a fundamental expectation of UT-Battelle and is accompanied by an expectation of full disclosure and a bias toward reporting. Based on current performance data and our most recent external reviews, we have drawn the following conclusions.

- Our worker safety and health performance is improving but is not yet "Best in Class." Safety performance is now comparable to averages for national laboratories but is not at the level represented by industry leaders.
- Although compliance with environmental requirements is effective, legacy issues are adversely affecting operational cost and safety. We face a substantial and costly effort to eliminate legacy materials that pose a hazard or impede facility revitalization.



For two quarters, ORNL's occupational safety performance exceeded expectations.

- Although radiological controls appear effective, an analysis of the potential for further dose reductions needs to be done and concomitant strategy developed.
- The supporting infrastructure for the move from an "expert-based" management system to a "standards-based" management system was complete by October 30, 2003.
- Improvements in the operational discipline and accountability culture, particularly in the areas of performance assessment and work control, are needed in selected areas of ORNL operations. This includes increasing emphasis on pollution prevention and waste minimization in work control.

Objectives and Strategies

Based on our situation analyses and strategic intent, we have established five objectives for the ES&H program.

Objective 1: *Achieve sustained "Best In Class" worker safety performance with a target of meeting the performance achieved at outstanding industrial laboratories.*

Strategy

- Create safer work spaces through implementation of the laboratory space manager initiative.
- Address culture and behavior change through implementation of behavior observation programs and management training.
- Conduct Integrated Safety Management maturity assessments, analyze evluations results, and take appropriate corrective actions to ensure continuous feedback and improvement.

- Implement peer worker incentive and case management programs to drive down injury rates.
- Communicate our expectations of full accountability for operational performance to line management at all levels through our management programs.

Objective 2: *Eliminate environmental vulnerabilities and legacy materials from our facilities.*

Strategy

- Minimize the Laboratory's hazardous material footprint through
  - — identification of all chemicals across the Laboratory and
  - — reduction of the quantity of excess / surplus chemicals procured and managed at ORNL in order to support ORNL's overall goal of reducing hazardous waste by 90% by 2005.
- Identify environmental vulnerabilities and develop and implement a prioritized plan for mitigation (e.g., liquid and gaseous waste systems).
- Identify legacy materials and develop and implement a prioritized plan for disposition.
- Prepare for assumption of the management of newly generated waste responsibility and long-term stewardship.

	FY 2002	FY 2003	Total
Trucks/moving vans to ORNL Property Sales	13	89	102
Tons scrap metal recycled	60	599	659
Wood materials burned (yd^3)	9	360	369
Gas Cylinders	766	322	1088
Material to landfill (yd^3)	81	590	671
LLW to Envirocare (yd^3)	333	556	889
Excess chemicals (processed or in process)	0	14,089	14,089
Pumps & motors inventoried	0	1,915	1,915

Significant progress has been made in disposition of legacy materials.

Objective 3: *Verify effectiveness of ORNL radiological controls.*

Strategy

- Perform an analysis of the potential for further dose reduction by reviewing the necessity and justification for all work resulting in radiological exposure.
- Develop and implement practicable approaches to achieve dose reductions.

Objective 4: *Complete and enhance effective ESH&Q systems and tools.*

Strategy

- Complete Standards-Based Management System (SBMS) infrastructure by replacing remaining legacy policies and procedures.
- Verify implementation of our policies, standards, and procedures throughout the Laboratory through performance assessment and independent oversight.
- Increase customer understanding of and satisfaction with the SBMS through the development of value metrics.
- Seek third-party accreditation to increase stakeholder confidence we are operating according to industry consensus standards of
  ISO 9000 Quality Management,
  ISO 14001 Environmental Management, and
  ISO 17025 Calibration and Testing Laboratories.

Objective 5: *Enhance the maturity of our self-assessment program.*

Strategy

- Conduct periodic evaluations of line management performance assessment to verify the effectiveness of line management's approach to utilizing business planning and assessment and to incorporating analyzed performance assessment data for feedback and improvement.
- Conduct Integrated Safety Management (ISM) Workplace Maturity Evaluations to allow line managers to measure the maturity of their implementation of ISM in their work spaces using a consistent framework and ranking structure.
- Conduct Management System Maturity Evaluations to monitor progress towards meeting performance objectives in support of business plans and to assist management system owners in the effective, efficient, and well-deployed delivery and continued improvement of ORNL management systems.

Key Accomplishments

Sustained Improvement in Worker Safety and Health

- First-generation SBMS implemented—2002
- Initial Group Leader Training completed—2002
- ORNL's Integrated Safety Management under one centralized plan—2002
- 1 million hours of work completed without a lost workday away injury, achieved twice—2002
- Group Leader Recertification Training completed—2003
- 2 million hours of work completed without a lost workday injury—2003
- Total Recordable Case Rate (2.0) below Office of Science laboratory average and approaching "Best in Class" (1.8)—2003

Sustained Performance in Environmental Compliance

- No significant regulatory findings—2003
- No reportable releases to the environment—2003
- No reportable permit nonconformances—2003

Elimination of Environmental Vulnerabilities and Legacy Materials

- Chemical Management Center brokers transfer of 670 items to safe storage, transfer of over 2000 items to new users, and processing of over 500 items deemed not suitable for reuse as waste—2002
- Significant reduction in Laboratory's hazardous material footprint through disposition of chemicals and other materials (see chart on page 157)

Human Capital

Key Outcomes and Associated Performance Measures

The Human Resources (HR) Management System supports Oak Ridge National Laboratory (ORNL) management and staff by developing and implementing programs, processes, and policies that enable the Laboratory to attract, hire, develop, compensate, retain, and reward a highly qualified and diverse workforce within the guidelines of applicable labor agreements, federal and state laws, and regulations.

The HR Management System achieves high-level outcomes through its performance of the following functions:

Function	Role
Benefits Administration	Deliver a cost-effective benefits program that meets the needs of our employees and their dependents.
Compensation	Maintain a wage and salary program that is externally competitive and internally equitable, ensuring the Laboratory's ability to attract and retain a talented workforce.
Concerns Program	Provide an alternative route for employees, guests, and visitors to freely express concerns and issues without fear of retribution.
Diversity Programs	Establish programs that promote inclusion and encourage recruitment and retention of a highly skilled, diverse staff. In addition, support management to ensure compliance with all federal, state, and local Equal Employment Opportunity and Affirmative Action regulations.
Employee and Organizational Development	Provide employee skill enrichment programs to enable staff to develop necessary capabilities. Maintain systems and programs to enhance general management capabilities and nurture the ongoing development and availability of strategic skills within the workforce.
Human Resources Information Systems and Employee Records	Provide systems, procedures and controls to enable ready access, analysis, and protection of employee records and information.
Human Resources Management Services	Provide advice and counsel to employees and management on HR policy, procedures, and strategy. Deploy the HR Management System to ORNL through HR Managers assigned to Directorates.
Labor Relations	Provide strategies, leadership and day-to-day coordination of efforts to maintain an effective partnership with the bargaining unit workforce.
Quality of Work Life	Maintain assessment mechanisms to understand the needs of staff and facilitate implementation of approaches to establish UT-Battelle as an "employer of choice."
Staffing Management	Provide expert design, development, and delivery of staffing assessment processes and internal/external recruitment systems.

The high-level outcomes include the following:

- Deliver high-value and effective HR programs and services that not only meet the needs of our research and support management and staff but also anticipate the future opportunities and challenges facing ORNL.
- Provides strategic leadership to maintain an organizational culture that attracts and supports a skilled diverse workforce and achieves our goal of being an "employer of choice."
- Ensure compliance with DOE requirements for human resource management and applicable laws and regulations.

ORNL offers an internship program for high school students through the Southeastern Consortium for Minorities in Engineering (SECME).

Situation Assessment

In late 2002, HR undertook an initiative to conduct a thorough self-assessment. As part of this activity, an external consultant was commissioned to conduct a thorough assessment of the structure and operations of HR to ensure that our efforts, capabilities, and approaches are aligned with and support the needs of our customers and stakeholders. This assessment included input from over 200 key stakeholders from general staff, line management, and the DOE site and operations offices. In addition, an internal evaluation of our performance assessment program was conducted in spring 2003, and these results were combined with the results of the externally led review.

Based on the results of these assessments, the following key challenges were identified.

- HR needs to clarify its role in customer and stakeholder service. Changes will be implemented based on a 3- to 5-year strategic plan that is being developed.
- The rewards program must be enhanced to maximize cost-effectiveness, value, and organizational improvement and motivate improved staff performance at all levels.
- Underutilization of women and minorities in several categories, as measured by Affirmative Action goals and metrics, must be reduced through a commitment to diversity and implementation of effective recruiting and outreach approaches.
- Some staff are concerned about their ability to raise issues and concerns without fear of retribution. The Concerns Program will be redeployed to address this issue.
- ORNL faces sustained increases in the costs of benefits. "Best practices" will be developed and implemented to contain these costs, as measured by standard metrics and identified benchmarks, including fringe rate and value comparisons. We must be cost-effective yet provide highly valued benefits for our staff.
- ORNL must maintain and grow its workforce in response to changing business needs. A staffing management strategy that ensures a highly skilled and diverse workforce must be deployed. In addition, we must develop knowledge management strategies that ensure ORNL will retain and develop critical skills and job knowledge.
- Our ORNL leaders continue to face challenges in managing a dynamic workforce. An enhanced leadership development program is being designed to expand staffing management and knowledge management capabilities.

Objectives and Strategies

Given the strategic and functional roles of our management system and our situation assessment, we have developed the following objectives for Human Resources.

Objective 1: *Focus resources and services on the business needs of our customers while developing and deploying cost-effective and strategic solutions.*

Strategy

- Enhance and maintain staff competencies through staffing and development actions and develop performance standards for service delivery. Evaluate the importance of HR services and the degree of satisfaction with those services in terms of what is important to the long-range success of ORNL.

Objective 2: *Expand the Employee and Organizational Development Program to ensure that the skills development needs of the Laboratory are being addressed.*

Strategy

- Reassess skills capabilities and conduct a gap analysis to identify requirements and shortfalls.
- Develop and implement cost-effective skills development approaches that are aligned with the missions of the Laboratory and address developmental needs throughout an employee's career.
- Continue the maturation of the Laboratory's succession planning process with a focus on addressing the development needs of future leaders.

Objective 3: *Design a cost-effective, high-value rewards program to maximize organizational effectiveness and promote improvement in individual performance.*

Strategy

- Leverage existing and deploy new (individual and team) rewards and recognition components focused not only on monetary rewards but also non-monetary options.
- Strengthen and reinforce pay for performance by establishing better standards and evaluation systems and improving staff and management education efforts.
- Develop and implement "best practices" to contain ever-increasing costs of benefits as measured against standard metrics and identified benchmarks, including fringe rates and value comparisons.

Key Accomplishments

- Completed the development of and conversion to a contemporary compensation system with eight independent pay structures and a new job classification system (2001).
- Completed a comprehensive review of benefits administration resulting in the transfer of five benefit plans to UT-Battelle and a cumulative cost containment of ~$13.1 M (2001–2003).
- Developed and implemented a Recruitment Tool Kit that supports our efforts to attract "strategic skills" (2002).
- Rolled out the Employee Self-Service Web-based tool, which provides employees access to their personal information and allows them to make changes (2002).
- Developed and implemented Roles, Responsibilities, Accountabilities, and Authorities to assist employees in better understanding position expectations (2001).
- Completed a three-year plan to adjust ORNL's R&D salaries to a market-competitive position (2002).
- Conducted a Quality of Work Life Survey and implemented several key initiatives to include reduction of one layer of management, creation of an on-site fitness center, and adoption of a floating holiday (2001 and continuing).

Objective 4: *Champion the assessment and enhancement of the workplace environment.*

Strategy

- Develop and conduct a workplace assessment and champion action planning to address issues identified.
- Assess employee understanding and engagement with the mission of the Laboratory and their work as well as quality of work life.
- Provide tools and services to enhance management's ability to increase employee understanding and engagement, as well as address issues related to quality of work life.
- Redeploy the Employee Concerns Program to enhance the existence of a workplace climate where employees feel free to raise concerns without fear of retaliation.

Objective 5: *Deploy a staffing management strategy that ensures a highly skilled and diverse workforce with particular emphasis on reducing underutilization of women and minorities. In addition, address the issue of "knowledge management" in the areas of critical skills and job knowledge.*

Strategy

- Develop and deploy a comprehensive workforce planning process to identify imminent and future gaps in talent, capabilities, and core competencies.
- Identify and implement "best practices" to strengthen our ability to recruit a diverse workforce and address strategic skills requirements.
- Identify key vulnerabilities by analyzing anticipated turnover trends and skill needs.
- Develop and implement programs and solutions to capture and retain critical knowledge.

Objective 6: *Review and revise our labor relations strategy to enhance positive union and management relationships in support of the Laboratory Agenda.*

Strategy

- Utilize an interest-based approach to guide our ongoing relationship with the bargaining unit.
- Develop our 2004 labor negotiations strategy and a follow-on strategy for the administration of the new labor agreement.

Objective 7: *Continuously evaluate and improve our programs and services using a rigorous self-assessment process.*

Strategy

- Employ self-assessment methods at the lowest operational level.
- Develop and communicate clear and meaningful performance measures.
- Identify and incorporate best practices.
- Conduct an ongoing evaluation of the importance and satisfaction with services and the delivery model.
- Articulate, cummunicate, and live a compelling set of core values including open communication, self-knowledge, competence, customer focus, and respect of individuals.

Safeguards and Security

Key Outcomes and Associated Performance Measures

The ORNL Safeguards and Security (S&S) Management System is designed to

- enable ORNL to conduct world-class science through the creation of a secure work environment;
- ensure the protection of DOE security interests (including information, people, and physical assets) necessary at the Laboratory to support the science mission; and
- ensure compliance with federal law, DOE, and other external regulatory requirements.

The outcomes we expect for our Safeguards and Security system include the following:

- Protect ORNL facilities, information, and physical assets against losses due to theft, diversion, and / or sabotage.
- Ensure compliance with all applicable safeguards and security rules and regulations, as measured by a robust, mature self-assessment system and recurring independent oversight.
- Enable the conduct of world-class science for ORNL staff, authorized guest assignees, and visitors to ORNL while maintaining a safe and secure workplace.
- Ensure positive control over all accountable nuclear materials at the Laboratory and the availability of nuclear material inventories critical to the performance of the R&D mission of ORNL.
- Demonstrate that the Integrated Safeguards and Security Management (ISSM) initiative is formally and effectively implemented.

Safeguards and Security (S&S) at ORNL is implemented through the Safeguards and Security Management System.

Management System Element	Role
Facility/Asset Protection	Devise risk-based protection strategies to ensure that DOE security interests, the site populace, and the general public are appropriately safeguarded.
Integrated Safeguards and Security Management (ISSM)	Ensure the orderly implementation of safeguards and security requirements.
Compliance	Comply with DOE and other external safeguards and security regulatory requirements, including the federal law, which prescribe a graded safeguards approach.
Information Protection	Ensure appropriate safeguards are applied to DOE classified matter, unclassified and classified cyber systems, to sensitive technologies, proprietary data, and other intellectual assets of the Laboratory.
Nuclear Material Control and Accountability (NMC&A)	Ensure appropriate graded safeguards are applied to all nuclear materials residing at ORNL.
Site and Facility Access	Enable site access for ORNL staff, site visitors, and guest assignees (foreign and domestic) with an official business purpose.

Situation Assessment

ORNL uses the results of a comprehensive, annual S&S self-assessment program, UT-Battelle oversight, and DOE and other external audits and reviews to determine the effectiveness of the overall Laboratory S&S program. The conduct of regular top-to-bottom line management self-assessments, supplemented by senior management engagement in the self-evaluation process, facilitates accurate assessments of the current status of S&S at ORNL. Based upon recent performance data and most current external reviews, the following conclusions were reached:

- DOE security interests, the physical assets of the Laboratory, and ORNL information assets are being adequately protected.
- Predominantly, the Laboratory is in compliance with applicable DOE and other external agency safeguards and security regulations. A notable exception involves the reliability of an aging site security infrastructure that requires upgrading and a more aggressive life cycle equipment replacement strategy as DOE funding permits. Also, the Laboratory currently has a strategy in place to ensure the Central Alarm Station (CAS) is housed within a hardened facility on the site, as required by DOE Order 473.1, Physical Protection Program, dated December 23, 2002.
- By maintaining the delicate balance between security needs and the science mission, ORNL S&S managers are enabling the effective conduct of science at the Laboratory even during times of heightened security.
- Through use of technology applications rather than more labor-intensive alternatives in resolving security issues and concerns, ORNL has effectively managed austere S&S direct funding resources. The application of proximity card technology within an automated access control system applied at the boundaries of laboratory facilities is one example of this continuing effort.
- By effectively planning for future nuclear material needs of the ORNL research community and by then ensuring the availability of required nuclear material inventories, ongoing research activities involving special materials are facilitated. Furthermore, through efficient documentation of nuclear material transactions, material accounting, material measurement and control, and material surveillance activities, the integrity of the ORNL nuclear material inventory is ensured.
- Notable improvements in line management acceptance of ownership for security throughout the work planning, work control, and work execution phases are evident at the Laboratory. The acceptance and application of the guiding principles and core functions of the ISSM framework have positively impacted the ORNL work culture and have aided immeasurably in the implementation of DOE S&S requirements.

Objectives and Strategies

Based upon our situational analyses and strategic intent, the following six objectives have been established for S&S:

Objective 1: *Provide required levels of physical protection for DOE security interests, the site populace, and other key assets as ORNL missions evolve and changes in the physical plant occur.*

Strategy

- Conduct performance tests and “force-on-force” exercises to validate that sufficient Protective Force manpower resources are available to provide DOE-mandated protection levels.
- Maintain an active life cycle replacement program for the security infrastructure of the Laboratory to preclude deterioration in security system integrity.

- Involve S&S subject matter experts in the engineering design phase of all new facility construction and development projects to ensure security system requirements are included in the plans early on to promote both cost-efficiency and proper security system design.
- Communicate our expectations for full acceptance by line management at all levels of responsibility for security in every work process involved at the Laboratory.
- Conduct recurring self-assessments to ensure protection program planning and safeguards and security operations are effective.

Objective 2: *Support the "virtual laboratory" concept by ensuring that a secure cyber infrastructure is maintained for ORNL automated information systems.*

Strategy

- Establish an appropriate network perimeter (firewall) to protect informational resources and information systems from unintended use or modification.
- Conduct a recurring cyber security self-assessment process.
- Provide appropriately secure remote access to Laboratory user facilities to enable authorized public and collaborator access to ORNL.

Key Accomplishments

- Ensured additional standoff protection for the staff and key ORNL facilities by assuming positive control over Bethel Valley Road in the aftermath of the events of September 11, 2001.
- Maintained a sustained heightened security posture at the Laboratory in the immediate aftermath of the events of September 11, 2001, and subsequently without adversely impacting the Laboratory's science mission.
- Established a second level of site security (installation of a new automated access control system) at the boundaries of occupied buildings at the Laboratory.
- Installed improved security systems, including a new Windows-based Velocity Alarm System for alarmed security points in Limited Security Areas (LSAs) and above at the Laboratory, thereby improving security alarm monitoring operator interface and system reliability; adding system expansion capability; and providing previously unavailable closed-circuit television (CCTV) system interface capability.
- Designed and arranged for fabrication of new electronic delay devices for special nuclear material (SNM) storage wells in Building 3019, the National ^{233}U Repository, thereby enhancing the security of this nationally prominent SNM storage facility.
- Developed and received DOE approval of a new ORNL Site Security Plan (SSP).

Objective 3: *Identify ORNL security issues or threat potential that could result in unacceptable risks.*

Strategy

- Conduct recurring threat analyses, appropriate risk and vulnerability assessments, radiological/toxicological assessments, and cost-versus-benefit analyses to ensure appropriate levels of physical protection are afforded critical assets.
- Apply timely remedies to correct any identified shortfalls in the ORNL security program.

Objective 4: *Ensure that positive control is maintained over any accountable nuclear materials retained by the Laboratory for either research use or for storage purposes.*

Strategy

- Require that all nuclear materials are requested, used, transferred, stored, received, and shipped in accordance with applicable Laboratory procedures and DOE order requirements.
- Conduct recurring internal assessments of nuclear material balance areas (MBAs) established to ensure strict accountability of these special materials.

Objective 5: *Provide an ongoing Integrated Safeguards and Security Management (ISSM) system and associated tools necessary to ensure security is considered in all aspects of work planned and performed at the Laboratory.*

Strategy

- Continue to provide ISSM feedback mechanisms.
- Conduct recurring self-assessment of ISSM program effectiveness.
- Provide recurring training to the ORNL staff on ISSM roles and responsibilities.
- Recognize excellent staff performance in ISSM.

Dedication of the West Access Control Portal on Bethel Valley Road.

Objective 6: *Enhance the maturity of the S&S self-assessment program.*

Strategy

- Conduct recurring annual self-evaluations of ORNL S&S activities to verify the effectiveness of program implementation and management.
- Conduct Management System Maturity Evaluations to monitor progress towards meeting performance objectives.

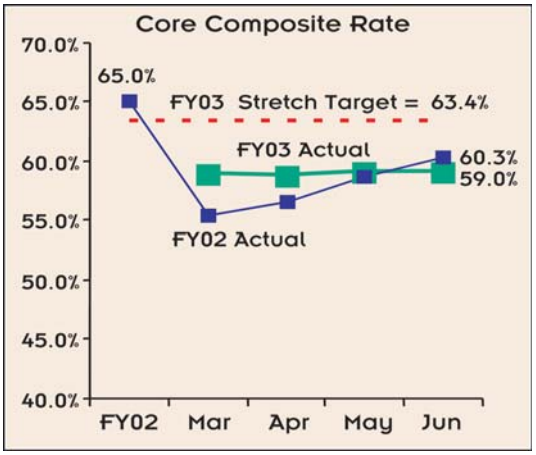
Financial Management

Key Outcomes and Associated Performance Measures

The Financial Management System's strategic intent is to enable world-class research and operations at ORNL by developing and operating a robust, effective financial system.

To realize this intent, ORNL has established a series of key outcomes:

- Lower the cost of doing business, as measured by the Core Composite Rate (CCR), a standard ORNL composite growth indirect cost metric.
- Deploy effective business planning and budgeting systems, as measured by publication of clear objectives for strategic research programs, indirect budgets for core business operations, and research business growth targets.



ORNL and DOE have developed a simple metric for tracking indirect costs. Lower numbers indicate that overheads make up a smaller fraction of ORNL labor rates.

The ORNL Financial Management System is implemented through five main roles.

Function	Role
Business Management Systems	• Process weekly costing to project accounts. • Maintain support and processes for costing of materials, subcontracts, labor, other direct costs, and effort. • Provide reporting on projects that are near and over budget thresholds.
Financial and analytical support to line and project management	• Develop and execute budgets. • Administer funds for DOE programs and Work for Others (WFO) projects. • Provide project reporting and cost analysis, including rates and budgets. • Develop charging guidelines.
Procurement, contracts, and property management support	• Assist project managers, business model owners, and other management systems with procurements, subcontracts, and contracts along with acquisition data, commitments, and cost data. • Provide proposal and contract support regarding items ordered, items received, payment approval, and contract terms and conditions. Also includes property control functions, inventory and control, and excess property disposal and property closeout.
Business analysis	• Conduct financial analysis for management (tracking of indirect cost rates, variances, and budgets, along with effort and organizational burden). • Conduct financial analysis for DOE (functional costs, metrics reporting, cost ceiling reporting, etc.). • Forecast business sales, business volumes, rates, financial variance, labor base, and FTEs.
Accounting support	• Ensure compliance with monthly MARS reporting to DOE; oversee nuclear materials accounting; analyze/reconcile general ledger accounts, annual financial statements to DOE, and monthly banking activities; maintain DOE letter of credit, the petty cash process; ensure compliance with federal and state tax reporting requirements; update the ORNL cost accounting disclosure statement; and support the UT-Battelle banking activities.

- Ensure compliance with applicable contract and DOE regulations and requirements, as well as with applicable Federal Acquisition Regulations (FAR) and Cost Accounting Standards (CAS) rules.
- Provide the necessary tools for R&D project managers to oversee projects effectively, as measured by no cost overruns.

Situation Assessment

ORNL combines the results of our self-assessment program, internal audit oversight activities, and external audit reviews to determine the overall effectiveness of our Financial Management System and tools. Based on the current performance data and our most recent external reviews, the following conclusions can be drawn:

- We have substantially reduced the cost of doing business at ORNL but have not yet achieved best-in-class performance.
- ORNL faces substantial cost pressures for facilities modernization, legacy materials disposition, consolidation of laboratories and staff, and staff and retiree medical programs.
- Improvements to our budgeting and planning process are on track.

Objectives and Strategies

Objective 1: *ORNL will reduce core indirect costs as a fraction of total Laboratory funding.*

Strategy

- Assign breakthrough teams to areas where significant cost reductions may be possible.
- Constrain indirect rates below escalation through our planning and budgeting process.
- Track cost savings versus investments made.

Objective 2: *Improve financial and business systems for Laboratory staff and management and for our research partners.*

Strategy

- Develop workable financial and business models for joint research institutes between the Laboratory and universities.
- Implement new SAP modules and tools to provide better support to line and project managers.
- Pilot a new Web-based application for cost planning against Work Breakdown Structures (WBS) for tracking Budget Authority (BA) and Budget Obligations (BO), along with cost plan.
- Provide financial support and analysis to Strategic Planning for proposal success.

Key Accomplishments

- Implemented the "Indirect Overhead Stack" a portfolio method to manage and report overheads—2000.
- Implemented ORNL Flash report to track key operational and business growth performance indicators—2001.
- Simplified average chargeout rate system for compliance with DOE requirements and better project management—2001.
- Obtained bond financing for infrastructure revitalization—2002.
- Better managed organizational burden as Laboratory-level resource and improved rate stability—2002 and 2003.
- Developed the Core Composite Rate for measuring indirect cost performance and business growth in a single metric—2003.
- Reduced indirect cost by $30 million—2000 through 2003.

Objective 3: *Develop a fully integrated planning, budgeting, and assessment system.*

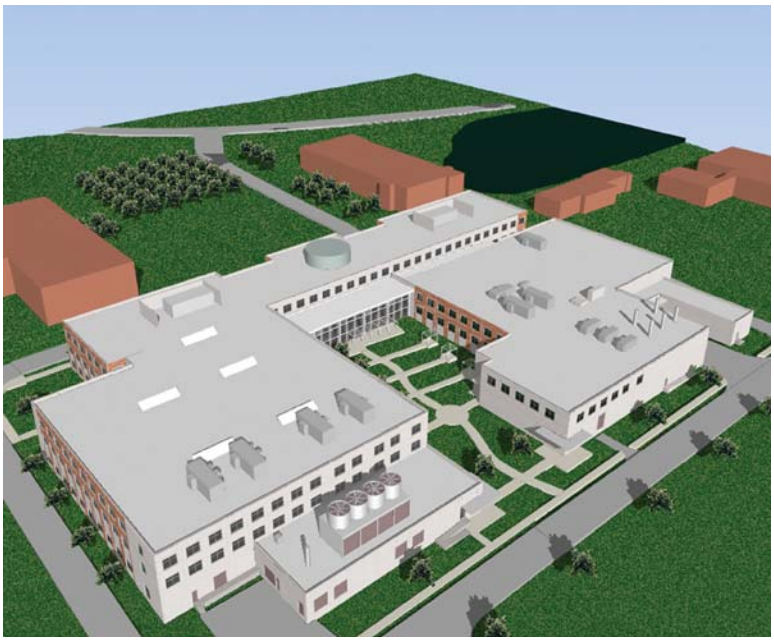
Strategy

- Complete implementation of the Management System process and integrate with Standards-Based Management Systems.
- Provide support to the Laboratory-level LDRD and planning process.

Objective 4: *Improve compliance and controls within Financial Management.*

Strategy

- Implement a finance training program to train staff on regulations, requirements, and standards.



Artist's conception of third party–financed buildings at ORNL.

Information Technology Management

Key Outcomes and Associated Performance Measures

We will enable world-class research and support services through reliable, robust, secure, and cost-effective information technology services and infrastructure.

The outcomes we expect for our Information Technology Management System include the following:

- A reliable, cost-effective desktop computing and communications infrastructure that fully meets the needs of research and support staff.
- Reliable access to high-end scientific computing, large-scale data management, and advanced scientific software for research.
- Reliable, secure high-bandwidth network infrastructure and network tools that enable computationally and data-intensive research access for remote users to ORNL scientific facilities.
- An integrated set of management information systems (MIS) that enable cost-effective management and support services.
- Appropriate security for all ORNL Information Technology (IT) resources and appropriate review and release for all ORNL scientific and technical information.

Roles

The ORNL Information Technology Management System is implemented through the following functions:

Function	Role
Information Technology	Provides a high-performance, cost-effective information infrastructure in support of the Laboratory's scientific, technical, and administrative programs. This includes design, development, maintenance, and operation of information infrastructure components including review and release of scientific and technical information, classification, electronic forms, e-mail, calendar, networks, servers, telephones, video, desktop support, business applications management, etc.
Safeguards and Security	The cyber security requirements are outlined in the Safeguards and Security Management System, which provides formal organized process for planning, performing, assessing, and improving the secure conduct of work in accordance with risk-based protection strategies.

Situation Assessment

The process of implementing a gigabit Ethernet campus backbone at ORNL is 60% complete. In the target topology, general office connectivity is 10/100 Mbps Ethernet. Gigabit links (copper and/or fiber) are provided to servers, labs, etc., by special request. ORNL is connected to ESnet via an OC-12 SONET circuit (622 Mbps), to the Southern crossroads (SoX) at OC-192 (10,000 Mbps), and to Internet-2 at OC-48 (2.5 Mbps).

Viruses, external probes, and system vulnerabilities continued to increase. New tools were developed, and comprehensive cyber security self-assessments of all divisions have been completed. ORNL anticipates the continuing development of security issues requiring rapid, effective response.

Scientific and technical information (STI) is a primary product of ORNL's R&D efforts. Unless specified otherwise by the sponsor, ORNL research activities culminate in STI that is shared with researchers and the general public worldwide. Many of these publications (e.g., conference papers and technical reports) are forwarded in electronic format to DOE's Office of Scientific and Technical Information, wherer they are made available for downloading on DOE's Information Bridge (http://www.osti.gov/bridge).

ORNL's mass-storage facilities are capable of storing the output of on-hand supercomputers at a rate which is adequate to their current usage profiles. Furthermore, there are no known bottlenecks in the High-Performance Storage System (HPSS) that might limit ORNL's ability to store or retrieve data. However, there is no currently available network transmission mechanism using the TCP/IP protocol (the most widely used protocol in the Internet) that can support bulk data transfers over congested wide-area networks at adequate rates. ORNL has activities under way to use automatic mechanisms to tune the performance of TCP/IP transfers, to use a different protocol to support multiple parallel transfers, and to use storage nodes located in the network. Each mechanism has shown promise, but none exhibits sufficient performance, and none is ready for production.

ORNL is currently using a plethora of visualization software tools to accomplish the needs of computational science teams. A number of immersive and quasi-immersive environments that integrate computation and graphics servers with video technology are also being utilized. We are exploring strategies which separate computation from rendering, allowing a modular configuration. On the display end, a new modular structure is being deployed for the Cave which offers new immersive configurations. A PowerWall strategy has also been developed for driving tiled walls. Data transfer models are being explored for eventual integration with visualization. The issues of data location as well as how to get the "right" data from a number of available datasets or subdatasets are critical. Visualization staff are working these topology, selection, and transfer issues, as well as the issue of collaboration topology.

Objectives and Strategies

Based on our situation analyses and strategic intent, we have established the following objectives and strategies for meeting these objectives:

Objective 1: *Provide state-of-the-art network connectivity for ORNL researchers and external collaborators and facility users.*

Strategy

- Continue to improve campus networking to enable gigabit connectivity to every major building/facility.
- Upgrade ESnet connectivity to at least OC-48.
- Continue to participate in regional and national high-speed network test-bed initiatives.

Objective 2: *Protect information on ORNL automated information systems commensurate with risk of loss and harm, and protect access to and from automated information systems on the Oak Ridge Network (see Safeguards and Security Management System).*

Strategy

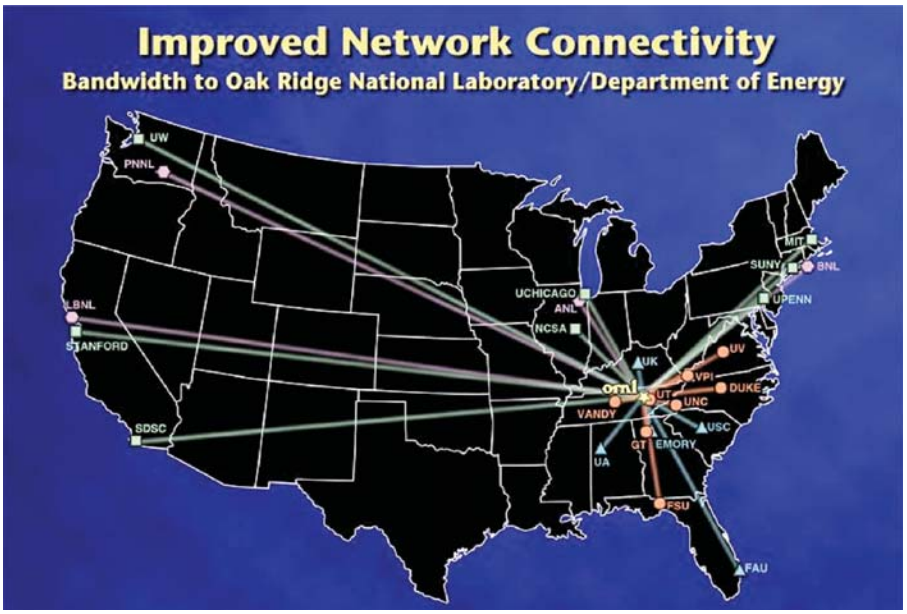
Integrate information and cyber security protection into IT infrastructure and normal staff work practices by

- implementing enabling IT that supports cyber security protection at the network, system, and application level;
- providing ORNL staff-approved work flow processes and requirements; and
- educating ORNL staff through the combination of regular and special specific cyber security awareness training.

Objective 3: *Ensure a data storage infrastructure adequate to accommodate anticipated supercomputing and data analysis requirements.*

Key Accomplishments

- Gigabit campus backbone established with five regional hubs.
- ESnet connectivity upgraded from OC-3 to OC-12 (155 to 622 Mbps).
- OC-192 installed between ORNL and SoX (enabling direct connectivity to I2).
- ORNL Internet firewall infrastructure developed and "default deny" firewall rules implemented for all ORNL servers.
- Relocation of ORNL networks, main computer room, and IT staff to new Computational Sciences Building was successfully planned and accomplished.
- Performance Evaluation Plan cyber security milestones were completed ahead of schedule and received an outstanding rating.
- Enterprise-level desktop virus protection with status reporting was implemented.
- A new cyber vulnerability tracking and resolution system was designed and implemented.
- Software called the Hierarchical Storage Interface was enhanced to provide a direct transfer path between HPSS installations using a very simple syntax. The performance of the code was considerably improved as well, so that it is now the fastest mechanism available which uses the TCP/IP protocol in transfers involving HPSS.



Strategy

- Develop improved data transfer mechanisms through participation in the High-Performance Storage System (HPSS) collaboration.
- Maintain a balance between computing capabilities and data storage and management infrastructure investment.

Objective 4: *Provide advanced visualization capabilities.*

Strategy

- Deploy state-of-the-art visualization tools and hardware.
- Rapidly introduce advances in visualization software into practice at ORNL.

Site and Facilities Management

Key Outcomes and Associated Performance Measures

The strategic intent of the ORNL Site and Facilities Management is to provide the physical structures, utilities, related infrastructure, and supporting operating staff to serve as the platform for conducting world-class research. To realize this intent, ORNL has established a series of key outcomes:

- Revitalize ORNL's research facilities to provide a modern, cost-effective physical plant, as measured by on-time, on-budget, as-promised construction of in-process and planned facilities funded by DOE, the state of Tennessee, and private sector financing and completion of planning for a Phase II Facilities Revitalization Program. The Phase II program will include the next state-funded joint institute, follow-on private sector–funded facilities, and new DOE line items and general plant projects. Completion schedules for construction and commissioning of new facilities are as follows:
  - Laboratory of Comparative and Functional Genomics—September 2003 to permit operation in October 2003
  - Private sector facilities—September 2003 and complete move by FY 2004
  - State Joint Institute for Computational Sciences / Oak Ridge Center for Advanced Studies—March 2004
  - Advanced Materials Characterization Laboratory—March 2004
  - Research Support Center—September 2004
  - Center for Nanophase Materials Science—September 2006
- Successfully execute the new Facilities and Operations model (conventional and non-reactor nuclear facilities), as measured by effective operation and maintenance of ORNL facilities through a landlord-tenant facilities model, improvements in operational performance statistics and increased customer satisfaction, competitive space charge rates, improving facility condition indices, and improved trends in ES&H performance for the Facilities and Operations workforce.
- Consolidate ORNL staff and laboratories on the main ORNL campus, as measured by safe shutdown of excess facilities and completion of staff and laboratory moves.

Roles

Successful attainment of the ORNL science and technology initiatives can be best achieved in a modern physical environment that is conducive to scientific research. Facilities at ORNL must be operated in a self-sustaining and cost-effective manner that promotes safety and security and enhances science performance. ORNL is rapidly transitioning to provide modern efficient facilities that support the scientific missions and professional facility management. Critical roles of Site and Facilities Management are as follows:

Function	Role
Facility Modernization	Develop new facilities to enhance science infrastructure and to better attract/retain key scientists.
Facility Maintenance	Ensure safe, compliant, and efficient operation of ORNL facilities and supporting infrastructure.
Facility Disposition	Eliminate old, expensive space and properly dispose of abandoned space through facility transfer, maintenance in cheap-to-keep mode, or demolition.

Situation Assessment

The Office of Science laboratories, including ORNL, are facing increasingly difficult challenges due to old, expensive-to-maintain, and inefficient facilities. The existing facilities are in many cases incapable of meeting functional requirements necessary to support state-of-the-art science, present significant hazards to the Laboratory staff, account for a large percentage of ES&H events, and consume significantly more energy than current-generation facilities. In addition the quality of the work environment these facilities provide is not competitive with the private sector.

The current ORNL space distribution and condition statistics, as shown in Figs. 1–3 and Tables 1–3, support the basic situation assessment that significant upgrades in the ORNL science and infrastructure must be accomplished. The Office of Science must increase its investment in facilities and infrastructure or risk not being able to attract and retain today's scientists or support the next generation of scientific facilities. For ORNL, over $500 million in new facilities and operational improvements have been identified in the current planning horizon to address these concerns. In addition, there is a large backlog of excess facilities and legacy equipment that is not being addressed by the Environmental Management Program that will require significant investments by the Office of Science for proper disposition in the coming few years. The location of many of these facilities plays a critical role in plans to modernize our research campus.

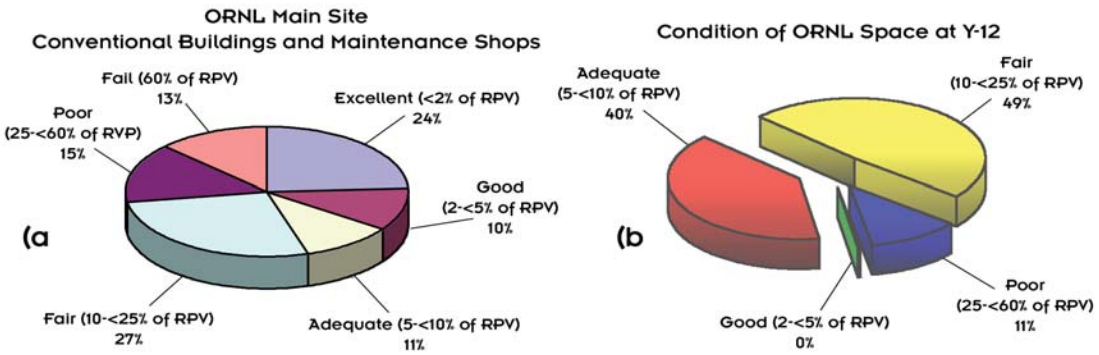


Fig. 1. Condition of ORNL space at main ORNL site and at Y-12, based on cost of modification or repair as a percentage of replacement value.

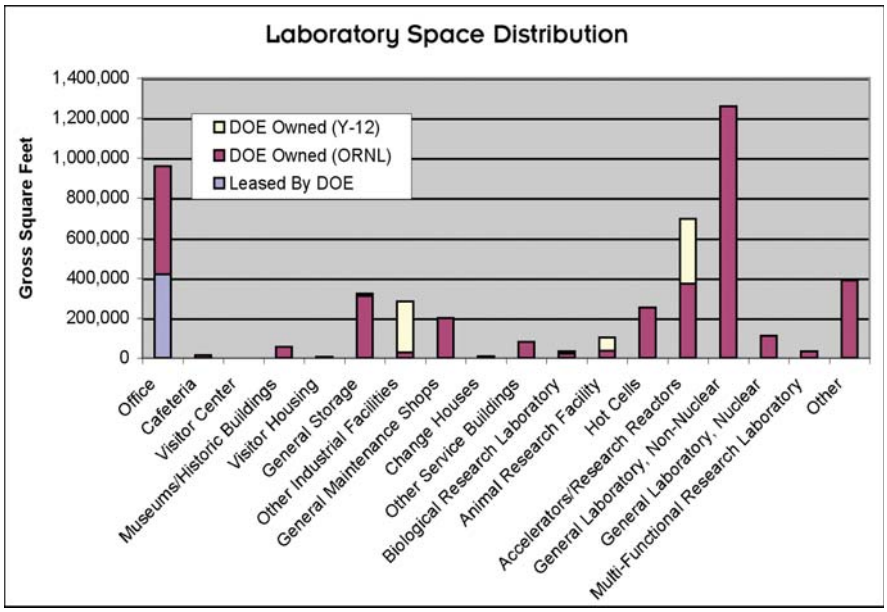


Fig. 2. Laboratory space distribution.

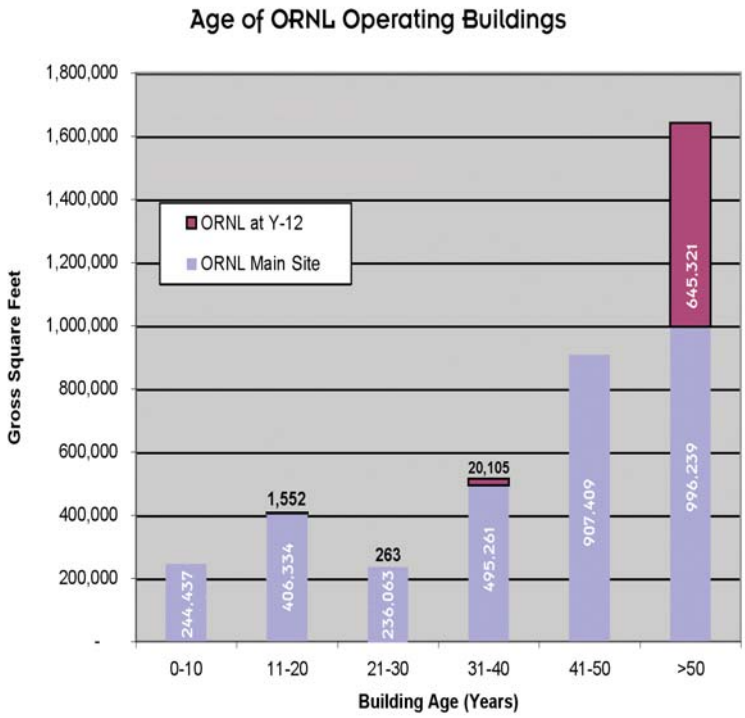


Fig. 3. Age of ORNL buildings.

Finally, it is clear that DOE has historically allocated a very low percentage of its available funding on basic facilities maintenance, and ORNL is no exception. As measured against plant replacement value ($4.6 billion for ORNL), we have been spending well below 2% on an annual basis, as compared to industry benchmark values of 3–4%. The new ORNL facilities operations model is designed to increase that percentage by placing greater emphasis on efficient maintenance operations as well as a reduction in the overall amount of maintained space.

Table 1. ORNL space distribution FY 2003

Location	Buildings		Trailers		
	Number	Space, ft²	Number	Space, ft²	Total space, ft²
ORNL main site					
UT-Battelle (SC)	263	2,847,438	36	32,369	2,879,807
UT-Battelle (SC-SNS)	5	80,342	5	8,640	88,982
UT-Battelle (NNSA)[a]	1	37,191	0	0	37,191
UT-Battelle (NE)	1	25,535	0	0	25,535
Bechtel Jacobs (EM)	83	218,549	26	30,669	249,218
Subtotal, ORNL main site	353	3,209,055	67	71,678	3,280,733
ORNL off-site					
Museum (AMSE)	3	56,583	1	552	57,135
ORNL at Y-12	10	667,241	1	680	667,921
Leased off-site	7	417,927	0	0	417,927
Total	**373**	**4,350,806**	**69**	**72,910**	**4,423,716**

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

Table 2. Estimated replacement plant value (RPV) for ORNL main site
(in millions of dollars)

Facility type	Replacement cost
Buildings and facilities	813
Utility systems	650
Programmatic Science Facilities	2100
All other	300
Total	**3863**

Table 3. Excess facilities disposition

	Fiscal year		
	2002	2003	2004
Excess facilities funding, $ in millions	3.13	2.16	0.76
Square feet eliminated, in millions	0.34	0.10	0.19

Objectives and Strategies

Based on our situation analyses and strategic intent, we have established four basic objectives for the Site and Facilities Management System.

Objective 1: *Improve operational performance in existing facilities.*

Strategy

- Implement the facilities operations model for conventional and non-reactor nuclear facilities; implement Integrated Safeguards and Security Management (ISSM) and energy conservation projects.

Objective 2: *Increase the scope, quality, and effectiveness of the facilities and infrastructure support services.*

Strategy

- Consolidate fabrication process, outsource cafeteria, expand the on-site services for transportation / packaging / chemical management / stores, upgrade emergency response plans and facilities to provide improved services.

- Continue benchmarking, self-assessments, and internal customer surveys to measure quality and effectiveness.
- Implement Facilities and Operations safety improvement plan with stretch goals in key areas, including STOP execution.
- Foster good relationship with the union, which results in enhanced work performance.

Objective 3: *Provide research facilities that meet the needs of modern science and technology through the design/construction of new facilities and the rehabilitation of existing space to serve the new science missions.*

Strategy

- Seek funding from DOE, the state of Tennessee, and the private sector for the design and construction of new research and support facilities. As shown in Fig. 4, the schedule for the initial phase of facility upgrades involves major construction activities through FY 2008, with follow-on efforts extending over the next 10 plus years. Project-specific funding requirements over the next 3 years are provided in Table 4, and a 10-year profile of overall DOE facilities modernization needs is given in Fig. 5.
- Ensure successful completion of Phase I of the Facilities Revitalization Plan. The first of the new DOE and private sector facilities became operational in late FY 2003.

Key Accomplishments

- Issuance of Facilities Revitalization Project Master Plan outlining private, state and DOE funding strategy for new facilities construction at ORNL (September 2000).
- Establishment of Facilities Operations Model for ORNL conventional facilities (October 2001).
- Selection of private sector project developer and initiation of construction for those facilities (February 2002).
- Execution of Facilities Use Agreements for all ORNL conventional facilities (October 2002).
- Completion of design and construction start for first state of Tennessee joint institutes (September 2002).
- Deactivation of over 700,000 square feet of excess space, including the transfer of 200,000 square feet of useable space to NNSA (October 2002).
- Establishment of the Facilities Operations Model for ORNL non-reactor nuclear facilities (March 2003).
- Completion of design and construction start for key DOE-funded research and support facilities: Laboratory for Comparative and Functional Genomics (July 2002), Advanced Materials Characterization Laboratory (June 2003), Research Support Center (June 2003), and Center for Nanophase Material Science (July 2003).

Objective 4: *Consolidate ORNL's research and support operations at the main ORNL campus and eliminate the abandoned space from the ORNL space inventory.*

Strategy

- Develop and implement a plan for exit of staff and laboratories from the Y-12 Plant, off-site leased space, and substandard ORNL facilities, accomplishing all critical moves by the end of FY 2004.
- Ensure appropriate cleanout of abandoned space, elimination of off-site leases, safe shutdown and surveillance of the excess government facilities, and ultimate transfer or demolition of those government facilities to eliminate long-term operations costs.

Table 4. Major construction projects: funded construction[a]
($ in millions—BA)

	Square feet	TEC[b]	Fiscal year 2002	2003	2004
Research Program Line Item Projects					
Spallation Neutron Source	600,000	1,192.70	276.30	210.57	123.87
Laboratory for Comparative and Functional Genomics	36,660	13.90	11.41	—	—
Center for Nanophase Materials Sciences	80,000	64.00	1.50	24.69	20.00
Energy Reliability and Efficiency Laboratory	52,000	19.50	—	—	0.74
Accelerator Improvement Projects					
Upgrade Building 6000, High-Power Target Laboratory	1,312	4.80	—	1.20	1.80
HB-4 Beamline		4.70	—	0.20	—
SANS Guide Hall, HFIR		4.30	3.34	0.77	—
General Purpose Facility Line Item Projects					
Fire protection system upgrade		5.89	3.12	2.19	—
Laboratory facilities HVAC upgrades		7.06	3.00	3.56	—
Research Support Center	50,000	16.04	1.50	4.94	9.60
General Plant Projects—Landlord					
Central Complex Facilities Upgrade		1.40	—	0.08	1.00
Building 7602 high bay upgrade		0.53	0.33	—	—
7625 High Bay Building	30,000	4.80	—	1.50	3.30
Fire protection upgrades		3.60	0.03	—	—
Electrical system upgrades		0.78	0.33	0.01	—
Building 1061 modification		0.21	0.01	—	—
Advanced Materials Characterization Laboratory	6,900	4.80	1.70	1.20	1.34
Nanoscience Metrology and Instrumentation Laboratory		1.80	0.90	0.04	—
6026 Gravel lot expansion/paving		1.16	0.54	—	—
6026 North parking lot		0.47	0.41	—	—
Miscellaneous parking lots		0.20	0.03	—	—
East campus telecommunications		2.45	—	2.20	0.25
General Plant Projects—Programmatic					
East and west portals	192	2.81	2.87	(0.06)	—
General Plant Projects—Institutional					
Quadrangle common area		2.93	—	0.26	1.37
Upgrade sewage collection, East Campus		0.28	0.02	0.26	—
East Campus utility modifications		0.60	0.05	0.06	0.49
Rebuild steam station and supply piping, 7920		0.68	0.05	0.63	—
ORNL wayfinding signs		0.28	0.24	0.04	—
Fifth Street entrance		0.21	0.21	—	—
Fifth Street/Southside Avenue parking lot		0.25	0.25	—	—
Southside Avenue parking lot		0.08	0.08	—	—
Roof replacement, 6007		0.17	0.12	0.05	—
7000 Area parking lot		0.10	0.10	—	—
East Campus storm drain modifications		0.48	0.05	0.42	0.01
East Campus infrastructure improvements		0.03	0.03	—	—
East Campus natural gas line		0.27	0.12	0.15	—
Central Avenue extension		1.76	0.04	1.43	0.29
Main entrance modifications		2.50	—	0.18	1.23
Facility upgrades, 4512		0.40	0.12	0.28	—
Road and parking lot paving		0.84	0.35	0.42	0.07
5510A Renovations—Metrology Laboratory		0.32	0.06	0.26	—
Building 1506 Renovations		3.00	—	0.53	2.47
SIOU parking lot		0.22	—	0.08	0.14
Building 5510 Upgrades		0.58	—	0.58	—
Fire Protection Systems Upgrade, 7930		0.26	—	0.26	—
4508 Power System Upgrade		0.10	—	0.10	—
Total funded construction		**1,374.24**	**309.21**	**259.28**	**167.97**

[a]Construction data as of January 2004.
[b]TEC = total estimated cost. May include funding from prior years.

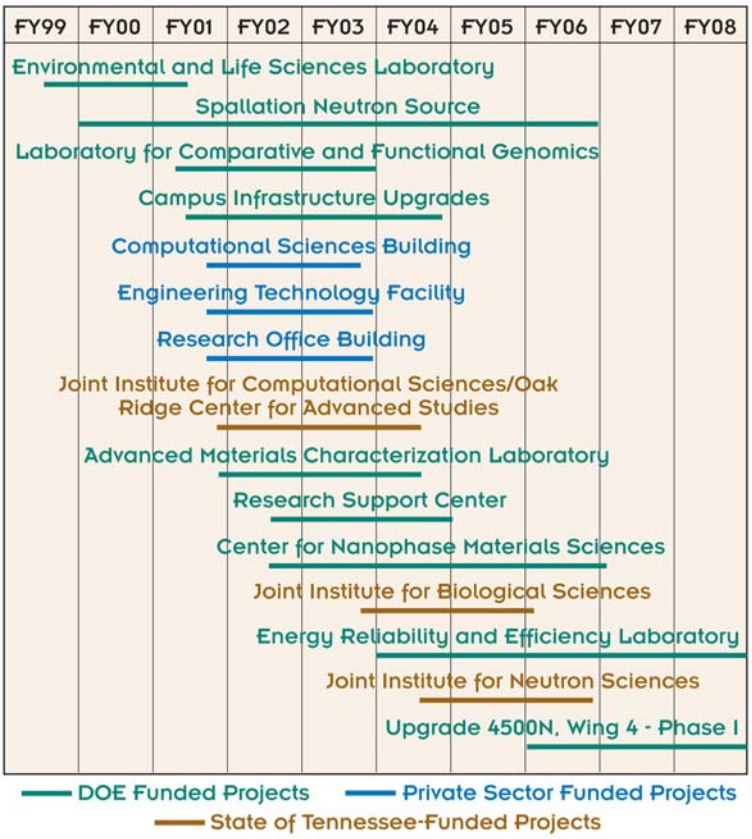
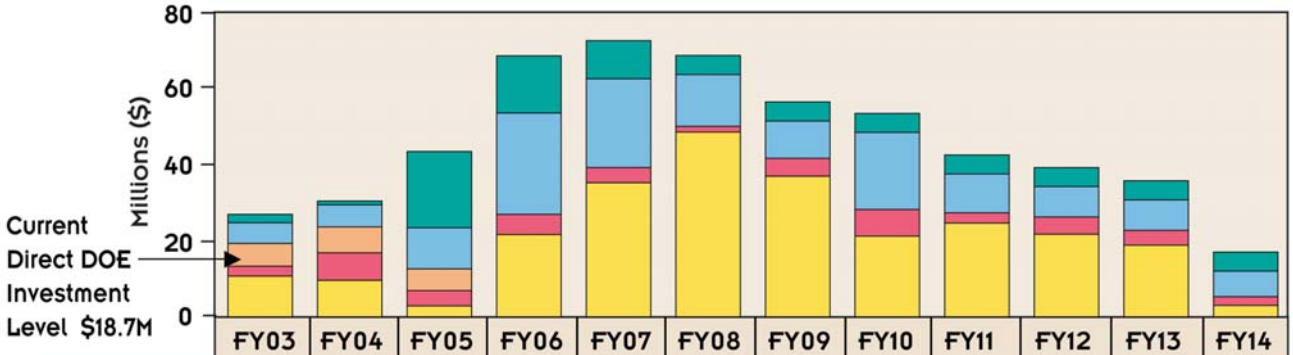


Fig. 4. Preliminary schedule for ORNL site development.



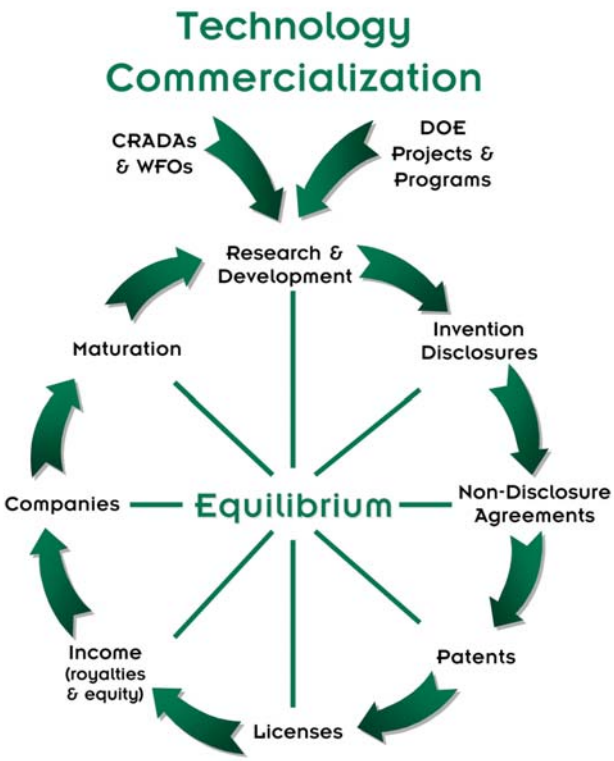
	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10	FY11	FY12	FY13	FY14
Excess Fac	2.2	1.0	20.0	15.0	10.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
GPP	5.4	5.8	10.8	26.6	23.3	13.6	9.8	20.2	10.2	8.0	8.0	6.7
IGPP	6.0	6.8	5.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GPE	2.6	7.2	4.0	5.3	4.0	1.5	4.7	7.0	2.7	4.5	3.9	2.3
Line Items	10.7	9.6	2.9	21.6	35.2	48.5	36.9	21.2	24.6	21.7	18.8	3.0

Fig. 5. Needs chart for ORNL landlord-funded infrastructure modernization.

Technology Transfer and Economic Development

Key Outcomes and Associated Performance Measures

The purpose of the Technology Transfer and Economic Development (TTED) management system is to manage and maximize the benefits derived from returns on investment from the technology, intellectual assets, and facilities at ORNL through commercialization, cooperative research programs, technical assistance, and other forms of technology transfer. Such action will benefit our customers, staff, and the nation. The outcomes we expect from our TTED system are the following:



Commercialization of technology

- Leverage ORNL resources to the benefit of the region, as evidenced by expanded partnerships that support the DOE mission.
- Develop and maintain a relevant, high-value approach to technology maturation and commercialization. New metrics will be developed and implemented to track and assess the implementation of the refined TTED business model.
- Be recognized as "best in class" of technology transfer operations, as distinguished by the receipt of Federal Laboratory Consortium (FLC) awards.
- Identify and protect intellectual property (IP) and proprietary information by fostering and encouraging the disclosure of inventions and by providing a system that ensures confidentiality.
- Match products to commercial and government needs and business needs to existing ORNL technologies, as demonstrated by the formation of new companies and the maturation of existing companies.
- Ensure that sponsored research agreements such as Cooperative Research and Development Agreements (CRADAs) and Work for Others (WFOs) are efficient and effective by comparing the cost of putting those agreements in place to their overall value to ORNL.

Situation Assessment

Based on information gathered as a result of performance planning for FY 2003, the following issues are being addressed:

- The process of identifying commercially viable technology will be driven by business and market analysis in addition to current technical and legal evaluation.
- An education and awareness presentation has been developed for group leaders addressing the protection and commercialization of intellectual property, and a second presentation entitled

The TTED plays the following roles in transferring technology and benefits derived from federally supported research:	
Intellectural Property Management	Identify, manage, and protect Intellectual Property (IP) created by ORNL, and promote the commercialization of IP.
Technology Commercialization	Promote the development and commercialization of ORNL technology.
Economic Development	Promote local, state, and region economic development using ORNL technology, personnel, and facilities.
Collaborative Agreements	Manage collaborations with and arrange access to ORNL resources and personnel.

"Why Should I Care about Technology Commercialization?" is currently being presented to research divisions.

- An Operational Plan dealing with topics such as roles and responsibilities, workflow process maps, and operational guidelines for CRADAs, WFOs, and User Facility processes is now in place.
- New, locally based start-up companies are now required to become a member of a mentoring/incubation program, such as the Center for Entrepreneurial Growth, as a condition of any new license agreement.
- Orderly exit strategies and contingency plans are now being put in place prior to the execution of a license.
- A method to accurately track new company start-ups based on ORNL technologies/assistance has been developed.
- Feedback mechanisms from internal and external customers are undergoing improvements.
- Policies for the use of royalty funds are being modified to better support technology development.
- Profit/loss analysis by individual technology portfolios is now being done.
- Internal and external capabilities in the area of business intelligence and market analysis are being expanded.
- A distinctive marketing style for branding the reputation and work of ORNL technology transfer initiatives throughout the region is being designed.
- Performance evaluations will be expanded to include assessments on the use of technology transfer mechanisms within the research divisions to ensure they are operating at a high level of performance.
- An ORNL portfolio management committee will be created to make decisions concerning equity held in licensee companies.

Objectives and Strategies

Objective 1: *Promote the commercialization of ORNL intellectual property.*

Strategy

- Build new business analysis/marketing capabilities through improved understanding of customer requirements, product specifications, and market drivers and constraints.
- Structure commercialization portfolios into accountable business units and implement a formal portfolio management process.

- Match products to commercial and government needs and match business needs to existing ORNL technologies.
- Incorporate market analysis as a part of the decision making process for the Invention Disclosure Review Committee (IDRC).
- Use the "in-reach" program to encourage scientists to explore marketing their IP and help them protect their ideas.
- Institute an MBA student partnership program.
- Implement a new royalty sharing and recognition program.
- Prioritize all technology portfolios by degree of commercial potential.
- Establish a "leads list" to estimate the potential revenue from prospective licensees.

Key Accomplishments

- ORNL won 4 out of 22 Federal Laboratory Consortium (FLC) Awards—2002
- Four ORNL multiyear CRADA proposals were awarded funding. The DOE-SC Laboratory Technology Research Program awarded funding to only 12 proposals submitted by all 10 SC labs—2001
- ORNL executes, on average, 25 CRADAs each year, 50 private sector WFO agreements, and 70 user agreements. The funds to the Laboratory from these agreements total more than $20 million annually—2002
- A new Chattanooga Center for Entrepreneurial Growth (CEG) is being created based on the Tech 2020 model used locally at ORNL
- ORNL has approximately 130 active licenses that produce about $1.7 million in royalties each year—2002

Objective 2: *Increase ORNL's research and development capabilities.*

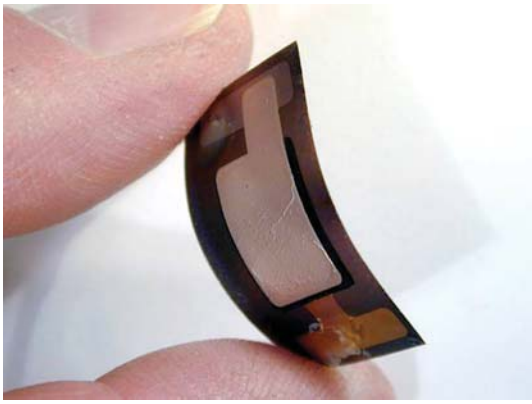
Strategy

- Facilitate interactions and collaboration with industry and academia that build scientific expertise and leverage funding and facilities using CRADAs, WFOs, and user agreements.
- Restructure the royalty and equity distribution to fund research and development activities that yield greater commercial success.
- Strengthen technology transfer ties with core universities.
- Address challenges of early-stage IP by obtaining DOE approval for and implementing Contractor-Funded Technology Transfer.
- Develop a process for acquiring private maturation funding.

Objective 3: *Promote economic development through initiatives that stimulate new company start-ups and maturation of existing companies using ORNL technology, personnel, and facilities.*

Strategy

- Make financial investments in the Technology 2020/Center for Entrepreneurial Growth (CEG) to expand its capabilities.
- Facilitate access to funding sources such as venture capital funds for early-stage technology.
- Support regional and local communities in technology-based recruiting strategies.
- Promote regional alliance partner initiatives through participation in the Tennessee Valley Tri-Lateral Alliance.
- Permit staff to pursue business interests via the entrepreneurial leave program.



ORNL's thin-film lithium batteries technology has been licensed to six different companies for applications in several areas including electronics, smart cards, and medical devices.

Objective 4: *Manage an effective and cost-efficient technology transfer program.*

Strategy

- Expand the metrics by which the ORNL technology transfer program is to be evaluated for performance to include all stages of the commercialization process.
- Assist with the prevention, recognition, and resolution of conflicts of interest involving technology transfer.
- Maintain fairness of opportunity.
- Update model license agreements to reflect current regulations and policies.
- Move TTED offices to the main ORNL campus to increase interfaces with research and development staff.
- Foster a culture shift within the TTED organization to a more business-like approach to operations.
- Evaluate the advantages of consolidating technology transfer efforts throughout the Oak Ridge area.

ORNL's Carbon Composite Bipolar Plate is an enabling technology for fuel cell–powered vehicles and will be indispensable in reducing the cost and weight of commercial automotive fuel cell systems.

Public Awareness and Community Outreach

Key Outcomes and Associated Performance Measures

ORNL strives to broaden the public's awareness of its science mission and enhance its image as a valued member of the community and region. To achieve this intent, the outcomes we expect include the following:

- An increased awareness of ORNL's activities among media and stakeholders at the local, regional, and national levels, as measured by media coverage and support among government and public stakeholders for the Laboratory Agenda.
- A Laboratory staff that receives timely and comprehensive information about strategies, initiatives, and events that have the potential to affect the performance of their work, as measured by coverage in employee news organs such as the *ORNL Review*, the newsletter *ORNL Reporter*, on-line news ORNL Today, and the Announcements, Visitors and Events Web site.
- Close, effective cooperation with DOE in addressing high-visibility issues and in emergency response and a stakeholder community that believes UT-Battelle is responsive to concerns and inquiries about the Laboratory, as measured by media commentary and DOE feedback.
- Significant impact on major civic projects and community needs, as measured by the number and success of volunteer activities and stakeholder feedback.
- A support for UT-Battelle's legacy investments in science education, civic projects, and economic development, as measured by the relevant stakeholders.

System Roles

Building support for the Laboratory requires a broad public understanding of ORNL's scientific mission, an appreciation of the mission's relevance to the national agenda, and the belief that ORNL is a valued member of the regional community. Public understanding and appreciation of ORNL are achieved through a variety of strategies:

External Communications	Provide the media and other stakeholders with timely and accurate information about Laboratory activities that underscore the value of ORNL.
Internal Communications	Disseminate among ORNL staff and retirees information necessary for understanding the Laboratory Agenda, increase awareness of current events, and promote a quality work environment.
Stakeholder Responsiveness	Assist DOE-ORO in responding to inquiries from public stakeholders.
Community Volunteerism	Coordinate the framework for a robust program of participation by ORNL staff in community volunteer projects.
Corporate Outreach	Allocate a significant portion of corporate funds in support of legacy investments in educational, civic, and economic development projects.
Emergency Management	Collaborate with DOE-ORO and state and civic officials to develop and execute an emergency response plan.

Situation Assessment

- ORNL's local, regional and national media coverage has grown steadily over the past three years.
- ORNL's internal communication instruments are widely read by staff and retirees, including *ORNL Today*, which receives approximately 25,000 hits each month, and the *ORNL Review*. However, some staff feel they are not adequately informed of Laboratory initiatives.
- UT-Battelle is recognized as the region's strongest supporter of science education and a major benefactor for area civic projects.
- Team UT-Battelle, the Laboratory's employee volunteer organization, enjoys strong participation in more than 25 projects each year, includes hundreds of volunteers, and is given broad coverage in the area media.
- DOE feedback indicates an excellent working relationship between ORNL and the DOE Public Affairs Office, and that ORNL support for the Joint Information Center is on target.

ORNL's visibility in the local, regional, and national media has been greatly expanded.

Objectives and Strategies

Objective 1: *Sustain current local and regional media coverage and seek to broaden exposure of ORNL on the national level.*

Strategy

- Nurture existing relationships with local and regional media.
- Target new media opportunities in national trade journals.
- Assist Laboratory research divisions in developing public releases, award nominations, and grant proposals.
- Host the Council for Advancement of Science Writing in October 2003.

Objective 2: *Enhance ORNL's internal communication efforts.*

Strategy

- Aggressively seek and report news of immediate internal concern to the ORNL staff.
- Assist the Laboratory Director and other members of ORNL management with internal and external communications.
- Provide support to the Laboratory Director for senior staff meetings and report the remaining relevant information to the staff.
- Provide monthly all-staff messages from the Director regarding issues and initiatives.

Objective 3: *Nurture the existing partnership between ORNL and the DOE Office of Public Affairs.*

Strategy

- Initiate daily conversations with the DOE Public Affairs Director and biannual meetings of both staffs to discuss current issues.
- Assist DOE-ORO in the planning and conducting of public meetings.
- Expand the number of speakers and presentations in the ORNL Speakers Bureau.

Objective 4: *Enhance and expand Team UT-Battelle programs.*

Strategy

- Coordinate at least 25 Team UT-Battelle volunteer projects in the region.
- Develop media coverage of Team UT-Battelle in Oak Ridge and Knoxville.

Objective 5: *UT-Battelle will maintain a robust program of legacy investments in education, civic, and economic development projects.*

Strategy

- Discussed in Science Education.

Key accomplishments

- ORNL has greatly increased its media coverage since 1999, including television segments beyond the Knoxville–Oak Ridge area, a six-part series on the "ORNL Renaissance" that appeared in the *Knoxville News Sentinel*, an international science news story on bubble fusion, and coverage by national media outlets.
- A successful bid was prepared to host the 2003 Council for the Advancement of Science Writing in Knoxville.
- An internal information campaign on campus modernization changes (a Web site, flyers, and news items that appeared in the *ORNL Reporter* and *ORNL Today*) provided information on a major change in ORNL's parking scheme and revised access control, as well as reduced the level of confusion and stress among the staff.
- An Announcements, Visitors and Events Web site was initiated that serves as a calendar of events for Laboratory staff and enables employees to submit individual items to the site.
- The *ORNL Review*, the Laboratory's science periodical, received international competition awards from the Society for Technical Communication for print and online publication in 2001, 2002 and 2003.
- More than 300 members of the community, including former Manhattan Project workers, attended ORNL's 60th Anniversary celebration.
- UT-Battelle logged its 5000th volunteer hour.
- UT-Battelle has contributed a number of successful community endeavors, including leading a successful fundraising campaign for the Oak Ridge Symphony.
- ORNL provided wide support to a variety of community organizations and efforts, including the UT-Battelle Scholars program, science laboratory equipment for 16 high schools, minority scholarships at the UT College of Engineering, the Oak Ridge Rowing Association, the Oak Ridge Archery Association, the Boy Scouts and Habitat for Humanity.
- Grants of $1 million helped establish the TennesSeed Fund, a venture capital fund to promote early stage development of new companies.
- ORNL has become a key partner with DOE in emergency preparedness planning and execution.

Objective 6: *Maintain a sound emergency preparedness communications plan at ORNL.*

Strategy

- Collaborate with DOE-ORO and the state of Tennessee in the continued establishment, training, and execution of Joint Information Centers during emergency operations.
- Assign and train ORNL staff to fill primary and secondary positions in Joint Information Centers.

Science Education

Key Outcomes and Associated Performance Measures

ORNL supports training of the next generation of scientists and engineers through access to ORNL research facilities and participation in ORNL research programs. ORNL is also committed to improving the quality of science education in our region and across the state.

Through our science education programs, we seek the following outcomes:

- Development of a diverse Science and Technology workforce in areas relevant to DOE missions, as measured by participation in and satisfaction with DOE assessments of ORNL student internships, graduate student research experiences, and post-doctoral programs.
- Significant strengthening of science education in our region, as measured by student participation and stakeholder feedback.

ORNL's program of science education outreach is designed to support DOE's mission of strengthening science education among students in primary and secondary schools. Using its unique facilities and staff resources, ORNL provides a broad spectrum of educational opportunities to more than 5000 students annually.

• K-12 Outreach	Provide resources and science education experiences that supplement the region's K–12 curriculum.
• Higher Education Internships	Coordinate research internships at ORNL offered through DOE's science education programs.
• Science Education partnership with with the University of Tennessee	Develop opportunities to support science education programs at the University of Tennessee.

Situation Assessment

Education programs for all levels, from pre-college through postgraduate, are offered by ORNL through contractual agreement with Oak Ridge Associated Universities.

- ORNL's K-12 Study Center and summer science camps annually provide science education experiences to more than 4000 students from some two dozen area and regional schools. UT-Battelle's program of corporate outreach funds a variety of science education–related initiatives, including science competitions and new science laboratories for high schools and middle schools.
- ORNL hosts a variety of successful internship programs in cooperation with the Oak Ridge Institute for Science and

The Director of Communications and Community Outreach joins gathered students and faculty of Tennessee School for the Deaf as they examine new science equipment and specimens. The items were purchased with a corporate gift to the school. UT-Battelle has donated a number of $10,000 gifts to other area schools as well—representative of the Laboratory's investment in the region's educational future.

Education programs also include students from the Appalachian Regional Commission, Vanderbilt University, and historically black colleges and universities.

- ORNL has established several science education partnerships with UT, including the UT-Battelle Scholars program, the UT Academy for Math and Science, and minority scholarships for the UT College of Engineering.

Objectives and Strategies

Objective 1: *Increase the number of schools and students participating in ORNL K–12 science outreach programs.*

Strategy

- Recruit additional schools to participate in Study Center programs.
- Increase number of summer science camp sessions.
- Make Lego League a premier high school competition in Middle Tennessee.
- Continue to fund new science laboratories in communities beyond Knoxville–Oak Ridge.
- Assist area teachers in obtaining state certification in science education by increasing the number of slots available to them in the UT Academy for Math and Science.

Key Accomplishments

- ORNL's summer intern program ranked the highest among five DOE laboratories, as evaluated by DOE Headquarters.
- UT-Battelle has funded 16 new science laboratories for area middle schools and high schools.
- UT-Battelle has increased the number of Tennessee teachers who annually attend the UT Academy for Math and Science from 6 to 40.
- The ORNL Study Center has become financially self-sustaining while providing science education experiences to more than 4000 students.
- ORNL invited local high school students to meet with a Nobel laureate as part of the laboratory's 60th anniversary.
- ORNL staff assisted the state of Tennessee in the review of K–12 science textbooks.
- Summer science camp participation increased from 19 to 60 students.
- UT-Battelle has provided more than $450,000 to the UT Academy of Math and Science and $75,000 to the UT College of Engineering.

Objective 2: *Maintain and enhance the quality of ORNL's summer internship program.*

Strategy

- Ensure appropriate placement and selection of interns based on performance standards set by the Oak Ridge Institute for Science and Education (ORISE).
- Monitor ORNL internship programs based on feedback obtained from participants through surveys and focus groups.

Objective 3: *Nurture science education partnerships with the University of Tennessee.*

Strategy

- Participate closely in the curriculum development for the UT Academy of Math and Science.
- Select outstanding candidates for the UT-Battelle Scholars program at UT.
- Provide scholarships to minority students in science and engineering at UT.

Laboratory Directed R&D Program

Through its Laboratory Directed R&D (LDRD) Program, ORNL performs innovative, leading-edge R&D that helps to maintain the scientific and technical vitality of the Laboratory, fosters creativity, stimulates exploration of forefront science and technology, and enhances the Laboratory's ability to address future DOE missions. The LDRD program often leads to productive new technical directions. It is funded through an overhead charge to the Laboratory's operating budget and has two components: the Seed Money Fund and the Director's R&D Fund.

The Director's R&D Fund promotes the development of new capabilities in support of the Laboratory's strategic plan. It is the chief means by which we develop capabilities consistent with the Laboratory Agenda to stay at the forefront of science and technology. Each year an annual call is made for proposals in specific thrust areas. In FY 2003, $13 million (about 80% of the LDRD budget) was allocated to support more than 50 R&D projects in advanced materials, complex biological systems, energy and environmental systems of the future, national security technologies, neutron sciences, and terascale computing and simulation science.

The Seed Money Fund supports innovative ideas that have the potential for enhancing the Laboratory's core scientific and technical competencies and provides a funding path for new approaches that fall within the distinctive capabilities of ORNL but outside the more focused research thrusts of the major Laboratory initiatives. Successful Seed Money Fund projects are expected to generate new DOE programmatic or Work-for-Others sponsorship at the Laboratory. Proposals are accepted directly from the Laboratory's research staff at any time of the year. Typically, 20% of the LDRD budget is allocated to Seed Money projects. In FY 2001, $3.6 million was used to support 65 projects.

LDRD accomplishments for FY 2003 ranged across all the disciplines at the Laboratory and are highlighted as follows.

- *materials science and engineering:* developed multifunctional nanocomposite materials; studied ultrahigh magnetic field processing of ferromagnetic materials for enhanced performance and energy savings; investigated biologically controlled synthesis and directed assembly of nanophase inorganic materials; and initiated the development of advanced techniques for atomic-level characterization of materials with aberration-corrected, ultrahigh-resolution electron microscopes.
- *neutron science and physics:* investigated the use of ultrafast high-power lasers for radioactive ion beam production, began a theoretical study of neutron star mergers, developed time-of-flight capabilities for studies of inelastic neutron scattering and dynamics of soft matter, and designed a technique for performing three-dimensional neutron structural microscopy.
- *chemical science and technology:* investigated protein surface mapping using chemical oxidation and mass spectrometry, began studying self-organizing polymers for use as biomaterials, studied the structure and dynamics of fluids in confined geometries, and developed reactive membranes for clean coal technologies.
- *computer and computational sciences:* developed algorithms for next-generation high-performance cellular architectures, electronic and nuclear structure calculations, and scalable climate models and began investigations into scalable visualization tools and technologies, advanced cyber

security, and high-performance computing of recognition principles in the complexes of biological macromolecules.

- *biological sciences and technology:* investigated a novel treatment for biological warfare pathogens, genetic variation in cellular responses to low-dose radiation, and high-throughput analysis and modeling of protein complexes and began studies of advanced techniques for molecular probing of live biological cells.
- *environmental science and technology:* modeled subsurface environmental processes, studied metabolic profiling in plants, developed a nondestructive in situ technique for evaluating contaminant immobilization in soil, and began investigations into ecosystem genomics.
- *engineering science and technology:* developed a two-wavelength spatially heterodyned interferometer for three-dimensional imaging, signal processing architectures for maskless lithography, nanoscale photonic crystal lasers, a new detector design for neutron imaging, and an infrared coherent anti-Stokes Raman scattering methodology for chemical detection.
- *nuclear science and technology:* developed a test loop for studying materials compatibility in advanced high-temperature reactors, investigated innovative safety technologies for generation IV reactor design, and began a project on multi-megawatt space reactor power system design.

The annual LDRD program plan, which is prepared and submitted to DOE-SC in accordance with DOE Order 413.2A, serves to provide a general description of and justification for the program and to request funding. Funding projections by fiscal year are shown in Table 1. The *FY 2002 Laboratory Directed Research and Development Annual Report* (ORNL/PPA-2003/1, March 2003) provides a program overview and project summaries for the LDRD Program.

Table 1. Laboratory Directed R&D funding summary by fiscal year
($ in millions)

	2002[a]	2003[b]	2004[c]	2005[c]	2006[c]	2007[c]	2008[c]
Seed Money	3.02	3.60	3.60	3.80	4.00	4.40	4.60
Directors' R&D	12.39	15.70	14.40	15.40	16.20	17.00	17.85
Capital Equipment	0.06	0.25	0.25	0.25	0.25	0.25	0.25
LDRD Total	15.47	19.55	18.25	19.45	20.45	21.65	22.70

[a]Actual costs.
[b]Program plan amounts; total allocation as of June, 27, 2003 is $16.65 million.
[c]Projected budget requests.

Resource Projections

Resource projections are presented in the following tables:

- Table R.1, Laboratory funding summary,
- Table R.2, Laboratory personnel summary,
- Table R.3, funding by assistant secretarial level office, and
- Table R.4, personnel by assistant secretarial level office.

These projections are based on funding requested in the FY 2004 budget submission documents, with some adjustments for subsequent guidance. They include some funding for construction that supports the major laboratory initiatives. In particular, capital equipment and construction funding estimates are provided for the Spallation Neutron Source (SNS).

In Tables R.1 and R.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 R.2 and R.4 are given as the number of full-time equivalent (FTE) employees/leased employees.

Additional detail is provided in the Supplemental Information appended to this report.

Table R.1. Laboratory funding summary by fiscal year

($ in millions—BA)

	2002	2003	2004	2005	2006	2007	2008
DOE effort	602.2	539.5	550.3	579.3	605.8	738.4	758.1
Work for others	85.6	109.2	128.5	135.6	145.2	156.1	165.8
Total operating	687.8	648.7	678.8	714.9	751.0	894.5	924.0
Capital equipment (excluding SNS)	19.3	16.3	15.9	24.0	22.1	23.1	18.4
Capital equipment, SNS	0.1	5.2	6.9	0.0	0.0	0.0	0.0
Capital equipment, Landlord GPE[a]	1.9	2.6	2.9	3.2	3.3	3.4	3.5
Construction (excluding SNS)	27.4	35.6	34.5	37.0	18.8	3.0	0.0
Construction, Landlord GPP[b]	4.2	5.4	5.7	6.5	7.2	7.8	7.8
SNS construction	276.3	210.6	124.6	79.8	41.1	0.0	0.0
Total ORNL	1017.0	924.7	869.2	865.8	844.2	932.7	954.9
Proposed construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total projected funding	1018.6	924.7	869.2	865.8	844.2	932.7	954.9

[a]GPE = General Plant Equipment.
[b]GPP = General Plant Project.

Table R.2. Laboratory personnel summary by fiscal year

[Full-time equivalent (FTE) employees]

	2002	2003	2004	2005	2006	2007	2008
Direct personnel							
DOE effort	1702.0	1709.1	1766.3	1720.5	1815.4	1899.2	1916.1
Work for Others	221.4	309.9	330.6	305.6	310.7	316.5	323.9
Department of Homeland Security	0	10.0	33.0	51.0	62.0	74.0	84.0
Total direct personnel	1923.3	2029.0	2129.9	2077.0	2188.1	2289.7	2323.9
Other	798.1	865.3	900.0	869.6	922.6	966.5	972.7
Indirect personnel							
Department of Homeland Security	0	9.0	29.0	45.0	55.0	65.0	75.0
Total personnel	1923.3	2038.0	2158.9	2122.0	2243.1	2354.7	2398.9

Table R.3. Funding by assistant secretarial level office by fiscal year

($ in millions—BA)

	2002	2003	2004	2005	2006	2007	2008
Undersecretary for Energy, Science, and the Environment							
Office of Science							
Operating expense	207.3	215.5	223.6	246.6	262.5	384.0	392.2
Capital equipment	16.9	15.4	13.2	20.0	20.6	21.5	16.8
Capital equipment, Landlord GPE[a]	1.9	2.6	2.9	3.2	3.3	3.4	3.5
Capital equipment, SNS	0.1	5.2	6.9	0.0	0.0	0.0	0.0
Construction (excluding SNS)	27.4	35.8	30.0	21.0	18.8	3.0	0.0
Construction, Landlord GPP[b]	4.2	5.4	5.7	6.5	7.2	7.8	7.8
SNS construction	276.3	210.6	124.6	79.8	41.1	0.0	0.0
Proposed construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total program	534.1	490.5	406.9	377.1	353.5	419.7	420.4
Office of Energy Efficiency and Renewable Energy							
Operating expense	118.1	124.0	128.7	132.6	137.2	142.0	147.0
Capital equipment	1.4	0.1	2.3	2.9	0.5	0.5	0.5
Construction	0.0	0.0	1.5	14.4	0.0	0.0	0.0
Total program	120.2	124.2	132.4	149.9	137.7	142.5	147.5
Office of Nuclear Energy, Science and Technology							
Operating expense	21.5	30.1	25.6	35.1	36.2	37.4	38.5
Capital equipment	0.0	0.4	0.8	0.8	0.9	0.9	0.9
Construction	0.0	0.0	3.0	1.5	0.0	0.0	0.0
Total program	21.5	30.5	29.4	37.5	37.1	38.3	39.5
Office of Fossil Energy							
Total operating	12.6	11.9	13.2	13.6	14.1	14.6	15.1
Energy Information Administration							
Total operating	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Office of Environmental Management							
Total operating	30.9	9.4	12.1	12.1	12.1	12.1	12.1
Capital equipment	(1.0)	0.0	0.0	0.0	0.0	0.0	0.0
Total program	29.9	9.4	12.1	12.1	12.1	12.1	12.1
Office of Civilian Radioactive Waste Management							
Total operating	0.1	0.2	0.5	0.5	0.5	0.6	0.6
Undersecretary for National Nuclear Security							
Deputy Administrator for National Nuclear Security							
Total operating	128.2	88.9	89.5	92.0	95.2	98.6	102.0
Capital equipment	2.0	0.4	(0.4)	0.4	0.2	0.2	0.2
Proposed construction	0.0	(0.2)	0.0	0.0	0.0	0.0	0.0
Total program	130.2	89.1	89.1	92.4	95.4	98.7	102.2

Table R.3 (continued)

	2002	2003	2004	2005	2006	2007	2008
Departmental Staff and Support Offices							
Office of Environment, Safety, and Health							
Total operating	2.5	1.8	2.1	2.1	2.2	2.3	2.4
Office of Counterintelligence							
Total operating	1.3	1.3	1.8	1.8	1.8	1.8	1.8
Office of Intelligence							
Total operating	0.0	0.2	0.2	0.2	0.2	0.2	0.2
Office of Security and Emergency Operations							
Total operating	0.1	0.2	0.2	0.2	0.2	0.2	0.3
Office of Policy and International Affairs							
Total operating	0.2	0.1	0.2	0.2	0.2	0.3	0.3
Office of Hearings and Appeals							
Total operating	0.1	0.0	(0.0)	0.0	0.0	0.0	0.0
Office of Worker and Community Transition							
Total operating	0.0	(0.3)	0.0	0.0	0.0	0.0	0.0
Environmental Management (Bechtel Jacobs Company LLC)							
Total operating	13.2	12.9	11.8	10.1	10.4	10.7	11.0
Subtotal DOE Programs							
Total operating	537.0	496.3	509.5	547.2	573.0	704.6	723.4
Capital equipment (excluding SNS)	19.3	16.3	15.9	24.0	22.1	23.1	18.4
Capital equipment, Landlord GPE	1.9	2.6	2.9	3.2	3.3	3.4	3.5
Capital equipment, SNS	0.1	5.2	6.9	0.0	0.0	0.0	0.0
Construction (excluding SNS)	27.4	35.6	34.5	37.0	18.8	3.0	0.0
Construction, Landlord GPP	4.2	5.4	5.7	6.5	7.2	7.8	7.8
SNS construction	276.3	210.6	124.6	79.8	41.1	0.0	0.0
Proposed construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	866.2	772.0	700.0	697.7	665.5	741.9	753.2
DOE Contractors and Operations Offices							
Total operating	58.6	36.3	33.4	24.4	24.8	25.6	26.2
Cooperative R&D Agreements							
Total operating	6.6	7.0	7.4	7.7	7.9	8.2	8.5
Total DOE Programs							
Total operating	602.2	539.5	550.3	579.3	605.8	738.4	758.1
Capital equipment (excluding SNS)	19.3	16.3	15.9	24.0	22.1	23.1	18.4
Capital equipment, Landlord GPE	1.9	2.6	2.9	3.2	3.3	3.4	3.5
Capital equipment, SNS	0.1	5.2	6.9	0.0	0.0	0.0	0.0
Construction (excluding SNS)	27.4	35.6	34.5	37.0	18.8	3.0	0.0
Construction, Landlord GPP	4.2	5.4	5.7	6.5	7.2	7.8	7.8
SNS construction	276.3	210.6	124.6	79.8	41.1	0.0	0.0
Proposed construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	931.4	815.3	740.8	729.8	698.3	775.7	787.9
Department of Homeland Security							
Total Program Funding	0	6.5	15.9	28.0	41.0	49.0	56.0
General Purpose Equipment (GPE)	0	0	5.9	6.0	0	0	0
General Plan Projects (GPP)	0	0	0	0	0	0	0
General Purpose Facilities (GPF)	0	0	0	0	0	0	0
Proposed construction	0	0	0	0	0	0	0
Total Projected Funding	0	6.5	21.8	34.0	41.0	49.0	56.0

Table R.3 (continued)

	2002	2003	2004	2005	2006	2007	2008
Work for Others							
Nuclear Regulatory Commission							
Operating expense	9.7	10.7	12.1	12.5	12.8	13	13.3
Department of Defense							
Operating expense	39.9	54.8	48.4	42.3	43.7	45.3	46.8
National Aeronautics and Space Administration							
Operating expense	5.3	8.9	14.4	14.4	14.4	14.4	14.4
Department of Health and Human Services							
Operating expense	1.6	0.8	2.1	2.2	2.3	2.4	2.5
Environmental Protection Agency							
Operating expense	3.9	4.2	4.9	5.1	5.3	5.5	5.7
Federal Emergency Management Agency							
Operating expense	1.2	0.9	0.9	0.9	0.9	0.9	0.9
Department of Transportation							
Operating expense	5.1	3.5	3.1	3.2	3.3	3.4	3.6
Other Federal agencies							
Operating expense	4.8	4.9	5.1	5.3	5.4	5.6	5.7
Electric Power Research Institute							
Operating expense	0.6	0.2	0.2	0.2	0.2	0.2	0.2
Other nonfederal agencies							
Operating expense	13.7	14.1	15.4	16.0	16.6	17.3	18.0
Total Work for Others							
Operating expense	85.8	102.9	106.7	102.0	104.9	108.0	111.0
Total ORNL							
Operating expense	688.0[c]	648.9	678.8	715.3	751.7	895.4[d]	925.2
Capital equipment (excluding SNS)	19.3	16.3	15.9	24.0	22.1	23.1	18.4
Capital equipment, SNS	0.1	5.2	6.9	0.0	0.0	0.0	0.0
Capital equipment, Landlord GPE	1.9	2.6	2.9	3.2	3.3	3.4	3.5
Construction (excluding SNS)	27.4	35.6	34.5	37.0	18.8	3.0	0.0
Construction, Landlord GPP	4.2	5.4	5.7	6.5	7.2	7.8	7.8
SNS construction	276.3	210.6	124.6	79.8	41.1	0.0	0.0
Proposed construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	1017.2	924.7	869.2	865.8	844.2	932.7	954.9

[a]GPE = General Plant Equipment.
[b]GPP = General Plant Project.
[c]SNS comes online.
[d]DOD conservative estimate.

Table R.4. Personnel by assistant secretarial level office by fiscal year

[Full-time equivalent (FTE) employees]

	2002	2003	2004	2005	2006	2007	2008
Undersecretary for Energy, Science, and Environment							
Office of Science							
Technical personnel	492.4	466.4	491.7	495.7	533.5	566.2	570.1
Other direct personnel	414.6	449.5	470.3	464.9	512.2	548.7	547.5
Total direct personnel	906.6	915.8	962.0	960.6	1045.6	1114.9	1117.6
Office of Energy Efficiency and Renewable Energy							
Technical personnel	161.8	162.8	174.6	177.7	178.8	185.5	192.6
Other direct personnel	104.5	105.0	111.1	112.8	114.7	119.0	123.7
Total direct personnel	266.3	267.9	285.7	290.6	293.5	304.5	316.3
Office of Nuclear Energy, Science and Technology							
Technical personnel	26.9	38.4	47.7	43.5	42.4	42.7	43.2
Other direct personnel	33.7	45.4	55.9	51.3	50.1	50.6	51.3
Total direct personnel	60.7	83.9	103.6	94.9	92.5	93.3	94.4
Office of Fossil Energy							
Technical personnel	22.3	23.3	24.6	24.5	24.5	25.2	26.4
Other direct personnel	8.3	8.7	9.7	10.4	10.4	10.8	11.3
Total direct personnel	30.6	32.0	34.3	34.9	34.9	36.0	37.7
Energy Information Administration							
Technical personnel	0.4	0.1	0.1	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	0.4	0.1	0.1	0.0	0.0	0.0	0.0
Office of Environmental Management							
Technical personnel	63.1	26.5	25.9	26.7	27.6	28.6	29.6
Other direct personnel	32.2	13.5	13.2	13.6	14.1	14.6	15.1
Total direct personnel	95.3	40.0	39.1	40.3	41.7	43.2	44.7
Office of Civilian Radioactive Waste Management							
Technical personnel	0.1	0.4	0.9	0.9	1.0	1.0	1.0
Other direct personnel	0.1	0.6	1.5	1.6	1.6	1.7	1.7
Total direct personnel	0.2	1.0	2.4	2.5	2.6	2.7	2.8
Undersecretary for National Nuclear Security							
Deputy Administrator for National Nuclear Security							
Technical personnel	66.9	69.3	72.5	74.7	76.9	75.0	71.6
Other direct personnel	83.0	96.4	100.7	102.2	104.2	103.7	102.1
Total direct personnel	149.0	165.7	173.2	176.9	181.1	178.8	173.6
Departmental Staff and Support Offices							
Office of Environment, Safety and Health							
Technical personnel	5.5	5.7	5.9	5.8	5.7	5.9	5.8
Other direct personnel	2.0	3.0	2.4	2.4	2.4	2.5	2.5
Total direct personnel	7.5	8.7	8.3	8.2	8.1	8.4	8.3
Office of Counterintelligence							
Technical personnel	1.1	1.3	1.4	0.0	0.0	0.0	0.0
Other direct personnel	7.0	8.0	8.4	0.0	0.0	0.0	0.0
Total direct personnel	8.1	9.3	9.7	0.0	0.0	0.0	0.0
Office of Intelligence							
Technical personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	0.0	1.0	1.0	1.0	1.0	1.0	1.0
Total direct personnel	0.0	1.0	1.0	1.0	1.0	1.0	1.0
Office of Security and Emergency Operations							
Technical personnel	0.2	0.2	0.3	0.3	0.3	0.3	0.3
Other direct personnel	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total direct personnel	0.3	0.4	0.4	0.4	0.4	0.5	0.5

Table R.4 (continued)

	2002	2003	2004	2005	2006	2007	2008
Office of Policy and International Affairs							
Technical personnel	0.6	0.7	0.5	0.5	0.5	0.6	0.6
Other direct personnel	0.0	0.0	0.0	0.0	0.2	0.2	0.2
Total direct personnel	0.6	0.7	0.5	0.5	0.7	0.8	0.8
Office of Hearings and Appeals							
Technical personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Federal Energy Regulatory Commission							
Technical personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Environmental Management (Bechtel Jacobs Company LLC)							
Technical personnel	5.7	5.6	5.3	4.5	4.6	4.8	4.9
Other direct personnel	15.4	15.0	14.1	12.1	12.4	12.8	13.2
Total direct personnel	21.1	20.5	19.4	16.6	17.1	17.5	18.1
Subtotal DOE Programs							
Technical personnel	847.5	801.6	851.3	854.8	895.8	935.6	946.1
Other direct personnel	701.2	746.6	788.3	772.5	823.5	865.7	869.7
Total direct personnel	1548.7	1548.1	1639.7	1627.4	1719.3	1801.3	1815.8
DOE Contractors and Operations Office							
Technical personnel	91.9	92.0	69.1	44.8	46.2	47.4	48.4
Other direct personnel	38.0	38.1	28.6	18.6	19.1	19.6	20.0
Total direct personnel	129.9	130.1	97.6	63.4	65.3	67.0	68.4
Cooperative R&D Agreements							
Technical personnel	19.9	26.2	24.7	25.3	26.1	26.2	27.1
Other direct personnel	3.5	4.6	4.4	4.5	4.6	4.6	4.8
Total direct personnel	23.4	30.8	29.0	29.7	30.8	30.8	31.9
Total DOE Programs							
Technical personnel	959.3	919.8	945.1	924.9	968.1	1009.3	1021.6
Other direct personnel	742.7	789.3	821.3	795.5	847.3	889.9	894.5
Total direct personnel	1702.0	1709.1	1766.3	1720.5	1815.4	1899.2	1916.1
Department of Homeland Security							
Total direct personnel	0	10	33	51	62	74	84
Work for Others							
Nuclear Regulatory Commission							
Technical personnel	17.7	25.6	28.1	28.2	28.2	28.2	28.2
Other direct personnel	6.3	9.2	10.1	10.1	10.1	10.1	10.1
Total direct personnel	24.0	34.8	38.1	38.3	38.3	38.3	38.3
Department of Defense							
Technical personnel	72.8	109.1	116.8	94.4	97.7	101.2	104.7
Other direct personnel	16.4	24.5	26.2	21.2	21.9	22.7	23.5
Total direct personnel	89.2	133.6	143.0	115.6	119.7	123.9	128.2
National Aeronautics and Space Administration							
Technical personnel	10.4	20.9	34.1	35.1	35.1	35.1	35.1
Other direct personnel	3.7	7.4	12.1	12.4	12.4	12.4	12.4
Total direct personnel	14.1	28.3	46.2	47.5	47.5	47.5	47.5

Table R.4 (continued)

	2002	2003	2004	2005	2006	2007	2008
Department of Health and Human Services							
Technical personnel	3.6	4.1	3.9	4.1	4.2	4.4	4.5
Other direct personnel	1.8	2.0	1.9	2.0	2.1	2.2	2.2
Total direct personnel	5.4	6.1	5.9	6.1	6.3	6.5	6.7
Environmental Protection Agency							
Technical personnel	14.2	14.3	17.5	18.1	16.9	17.3	17.9
Other direct personnel	3.0	3.0	3.7	3.9	3.6	3.7	3.8
Total direct personnel	17.3	17.4	21.3	22.0	20.6	20.9	21.7
National Science Foundation							
Technical personnel	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Federal Emergency Management Agency							
Technical personnel	1.9	2.2	2.1	2.0	2.0	2.0	2.0
Other direct personnel	0.8	0.9	0.9	0.8	0.8	0.8	0.8
Total direct personnel	2.7	3.1	3.0	2.8	2.8	2.8	2.8
Department of Transportation							
Technical personnel	7.4	7.8	4.6	3.9	4.0	4.1	4.3
Other direct personnel	8.0	8.4	4.9	4.1	4.3	4.4	4.6
Total direct personnel	15.4	16.1	9.5	8.0	8.3	8.6	8.9
Other Federal Agencies							
Technical personnel	5.4	8.7	7.6	7.4	7.5	7.3	6.9
Other direct personnel	2.8	4.4	3.9	3.8	3.8	3.7	3.5
Total direct personnel	8.2	13.1	11.5	11.2	11.4	11.1	10.4
Electric Power Research Institute							
Technical personnel	1.8	2.2	0.5	0.1	0.1	0.1	0.1
Other direct personnel	0.1	0.2	0.0	0.0	0.0	0.0	0.0
Total direct personnel	1.9	2.3	0.5	0.1	0.1	0.1	0.1
Other Nonfederal Agencies							
Technical personnel	30.6	38.8	36.5	38.1	39.4	40.2	41.8
Other direct personnel	12.6	16.0	15.1	15.7	16.3	16.6	17.3
Total direct personnel	43.2	54.8	51.5	53.9	55.7	56.8	59.1
Total Work for Others							
Technical personnel	165.9	233.9	251.8	231.5	235.3	239.9	245.6
Other direct personnel	55.5	76.0	78.8	74.1	75.4	76.6	78.3
Total direct personnel	221.4	309.9	330.6	305.6	310.7	316.5	323.9
Total ORNL							
Technical personnel	1252.2	1163.7	1229.9	1207.4	1265.4	1323.2	1351.2
Other direct personnel	798.1	865.3	900.0	869.6	922.6	966.5	972.7
Total direct personnel (FTE)	1923.3	2029.0	2129.9	2077.0	2188.0	2289.7	2323.9

Supplemental Information

Laboratory Directed Research and Development

ORNL's plans for Laboratory Directed Research and Development (LDRD) are described in Sect. 5.7 of the Institutional Plan. *ORNL Laboratory Directed Research and Development Program: Annual Report to the Department of Energy Summarizing Fiscal Year 2002* (ORNL/PPA-2003/1, March 2003) provides a program overview, funding summaries, and project summaries for the LDRD Program.

Work for Other Sponsors

Federal Organizations

Nuclear Regulatory Commission

ORNL supports the Nuclear Regulatory Commission (NRC) in nuclear safety, safeguards, and environmental protection activities by providing a technical basis for the NRC's licensing and regulatory actions and decisions. 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).

Work performed for NRC in support of its nuclear safety, safeguards, and environmental protection activities and in support of its licensing and regulatory actions and decisions is consistent with DOE's mission to increase the availability of clean, abundant energy; protection of the environment; and national security. This work also supports DOE's initiatives to maintain nuclear energy as part of the nation's future energy supply.

Reactor pressure vessel (RPV) integrity continues to be an area of emphasis for RES-sponsored programs at ORNL. Other current research areas for RES include burnup credit and high-burnup fuel issues for storage and transport of spent fuel, advanced reactor physics and probabilistic risk assessments (PRA), reactor operating experience reviews, and instrumentation and controls technology. Vulnerability assessments of nuclear facilities regulated by NRC continue and include studies of cyber security. Gas-cooled reactor activities (some of which are funded by DOE through NRC) include nuclear-grade graphite standards development, the analyses of high-temperature thermal and mechanical properties of irradiated graphite, and the identification of key issues associated with the safety of TRISO fuel. The modeling and performance of reactor accident simulations using the Graphite Reactor Severe Accident Code (GRSAC) continue. Also for RES, ORNL is compiling several radiological and dosimetric databases into a PC-based tool to assist NRC staff in confirming radiation protection calculations made by licensees.

Technical support for NMSS includes the areas of criticality safety, radiation protection, and heat transfer for nuclear fuel facilities and spent fuel cask designs; environmental review of licensee facilities; and a review of terminated materials licenses. Activities also include the development of recommended technical bases for regulatory criteria and guidance in storage, transport, and low-level waste facilities; training on special topics; support of International Atomic Energy Agency (IAEA)–coordinated research programs; and development of analysis capabilities for use in

licensing reviews. The ORNL-developed SCALE code system continues to be maintained and enhanced as a state-of-the-art computational tool used by NRC staff in performing license reviews for criticality safety, radiation shielding, and source terms.

Technical support for NRR includes fuel stability analyses, economic analyses, and assistance with rule-making activities related to environmental protection regulations. Technical support is also being provided to NRR for its review of advanced reactor designs and includes the development of cross-section libraries for the analysis of reactor core performance.

U.S. Department of Defense

ORNL continues to expand its 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. Where appropriate or necessary, programs are conducted in close cooperation and coordination with BWXT Y 12, LLC, and other research partners and include basic and applied research, development, technology demonstration programs, and prototyping.

The Joint Experimentation Office of Joint Forces Command, headquartered in Norfolk, Virginia, has become one of DoD's lead organizations in determining the direction of DoD transformation in Joint Warfighting by prototyping near-term capability and conceptualizing far-term directions. ORNL supports the proposed technology integration initiative to achieve better visibility of national laboratory capabilities and leverage that technology in areas where needs and capabilities match. ORNL has also been selected to represent all the national laboratories on the Science and Technology Working Group, which has been chartered to investigate the concepts and technology requirements for Joint Urban Operations.

Other work that ORNL is performing for DoD focuses on the science and technology challenges involved in envisioning, modeling, developing, and/or building the systems, platforms, and devices required to defend the nation's vital interests and protect members of its armed forces in the twenty-first century. ORNL expects to play a major role in reevaluating the future needs of the armed forces, with emphasis on the timely development and implementation of new technologies.

For FY 2004 and beyond, ORNL will pursue the development of programs in several areas of science and technology that present challenges to DoD, including

- chemical and biological detectors and sensors;
- scalable portable power systems that provide individuals the power to operate equipment for extended periods of time;
- personnel protection ensembles;
- filter technology for use in extended field operations;
- sophisticated navigational and tracking systems;
- lighter, stronger materials that can be adapted to meet a variety of needs, including individual protection, aircraft and combat vehicles, and improved fuel efficiency;
- intelligent software agents used to gather and synthesize data and organize information; and
- modeling and simulation and total asset visibility and decision support tools for military and commercial logistics and transportation applications.

Work continues on the development of a state-of-the-art field-portable Chemical/Biological Mass Spectrometer Block II (CBMS Block II), as well as miniaturized sensors and intelligent sensors on a

chip for point detection and standoff detection of chemical and biological agents. The CBMS Block II has now successfully completed chemical field trials at Dugway Proving Ground and is scheduled for fielding in the FY 2004 time frame. Completion of CBMS Block II biological capability is being planned for FY 2004 with fielding in FY 2005. Work is also under way to continue to evolve the biological capability to meet DoD biological detection programmatic requirements for field insertion in the FY 2009 time frame.

ORNL is currently developing a new power technology that combines a chemical-based hydrogen generator with a fuel cell to provide power on demand. This system will provide a number of key advantages, including power generation on demand, scalability over a wide range of power levels (10 W to 3 kW), and an inherently low signature. The system will be nontoxic, nonexplosive, and nonflammable.

In conjunction with core university partners (Georgia Tech Research Institute and North Carolina State University), ORNL is developing an integrated first responder uniform for use by DoD and other federal/local government agencies. The final configuration will include a suite of sensors to detect chemical, biological, radiological and nuclear hazards; a personnel cooling system; a biomedical monitoring system; acoustic, visual, and temperature awareness systems to increase situational awareness; and a regenerable oxygen system to allow operations in closed facilities.

ORNL will continue to pursue its historic strengths in developing filtering technology, but with DoD applications in mind. The development of filters that ensure clean water for soldier or noncombatant use would significantly enhance the ability of DoD to carry on extended military or humanitarian operations and reduce the supply burdens now placed on logistics systems. ORNL intends to perform a detailed market analysis to determine the need for this technology and the cost to develop it sufficiently to meet defense sponsor requirements.

ORNL is also developing sophisticated personnel/platform navigation and tracking systems for use by DoD. Such a system will be capable of providing accurate information, even in a Global Positioning System–denied environment. The merging of these technologies into a single system will enhance DoD's capability to more precisely locate assets on any type of battlefield.

Advanced carbon-based materials and infrared processing technologies are being developed to provide high-performance materials for aircraft and space applications involving unmanned and high-speed vehicles. ORNL's research on advanced composites has also resulted in development of special materials that have high thermal conductive properties that reduce heat signatures and increase survivability of soldiers and their equipment.

As additional support to DoD, ORNL continues to expand its capabilities in the use of autonomous intelligent software agents, which can be used to process information in ways that allow military personnel to make decisions more rapidly and to predict requirements in the defense supply chain.

The National Transportation Research Center (NTRC) plays a major role in ORNL's support of DoD. NTRC conducts research on vehicle designs, materials, and operations to improve the energy efficiency of the military vehicle fleet and transportation systems. New miniaturized instrumentation and sensors are being developed to improve detection of explosives and other contraband in cargo containers and baggage compartments and are also being evaluated for detection of unexploded ordnance and mines.

ORNL's transportation and logistics programs are also expanding their emphasis on military deployment activities. A major initiative has been the development of a collaborative planning tool that accelerates the planning and execution of the movement of troops and equipment while increasing the accuracy of information. This planning tool, the Collaborative Force Analysis Sustainment and Transportation (CFAST) system, is currently being evaluated by several planning staffs and commands around the world.

NSD has focused a major program ($8M / year for CFAST) and other transportation-related efforts around NTRC capabilities. NTRC must be positioned to move rapidly and decisively to capture and execute R&D and prototyping in the DoD and the Department of Homeland Security (DHS) markets (e.g., the Transportation Security Agency), and a second study has been proposed to explore this issue.

In FY 2004, there will be a determined effort to engage the U.S. Marine Corps, U.S. Navy, and the U.S. Air Force in utilizing ORNL technologies and expertise as they seek to modernize their forces. In working closely with DoD and the U.S. Army over the last few years, ORNL has developed the operational maturity to research and understand military needs and to find the right technology or expertise to meet each challenge. ORNL will also expand its educational outreach program with all branches of the service, as it has previously done with the U.S. Army in establishing a Training With Industry (TWI) Program.

Of importance to both DoD and DHS, ORNL has developed the capability to harness technology to identify, collect, tabulate, organize, and use information at "Machine Speed" from a variety of sources to solve technology challenges and issues. As part of its initiative to combat terrorism, NSD is leveraging the capabilities of ORNL, its core universities partners, ORAU, other DOE / DoD laboratories, and the private sector in launching the Technology Advantage Center (TAC). The TAC will find and evaluate (including testing) technologies for a given set of sponsor requirements; maintain a national database of homeland security technologies; monitor technology developments and evolving requirements; prepare technology roadmaps; conduct workshops and symposia; and work with DHS, DoD, and other agencies to develop ideas and solutions to national defense and homeland security issues. Initial areas of emphases will be on CBRNE (chemical, biological, radiological, nuclear, and high explosives) countermeasures—detection and decontamination technologies, cyber security, and critical infrastructure protection.

Toxicologists and health professionals at ORNL also contribute technical advice and assessments to ensure scientifically supported and health-based exposure criteria for chemical warfare agents. This work has provided the basis for military and civilian chemical warfare agent disposal determinations, military installation restoration programs, and chemical weapons treaty compliance. ORNL staff also develop and implement independent assessments of programs to ensure, monitor, and evaluate the quality of data used by DoD for making decisions in environmental remediation and risk assessment programs.

Finally, ORNL also continues to provide demographic and economic modeling support for planning, recruiting, and retention of military personnel, primarily for the reserve component.

U.S. Department of Transportation

ORNL assists the Department of Transportation's (DOT's) Federal Highway Administration (FHWA), National Highway Traffic Safety Administration (NHTSA), Federal Motor Carrier Safety

Administration (FMCSA), Federal Transit Administration (FTA), Federal Aviation Administration (FAA), and the Research and Special Programs Administration (RSPA) in research areas that include vehicle and highway safety, intelligent transportation systems, modeling and simulation, planning and systems analysis, data/statistical analyses and information tools, energy and environmental policy analyses, transportation operations, logistics and supply chain management, and technical assessment of oil and gas pipeline systems throughout the United States for compliance with regulatory standards. A major new initiative entitled the Heavy Vehicle Safety Research Center (HVSRC) was founded in FY 2002 at the National Transportation Research Center (NTRC). It serves as a research center in which government and industry work closely together to enhance the safety of heavy vehicles operating on our nation's highways and contribute to meeting national goals to reduce truck-related fatalities while maintaining and enhancing the economic viability of the U.S. trucking industry. The HVSRC involves a number of existing projects from various agencies within DOT and DOE that involve technologies or materials that are relevant to heavy commercial vehicle platforms. Additionally, the NTRC has received new congressionally directed funding in FY 2002 and FY 2003 amounting to $1.7 million in support of heavy vehicle safety research. Support from other sources includes capital equipment funds from the NTRC. Research conducted with these new funds involves heavy truck–infrastructure crash modeling, evacuation modeling involving heavy trucks, integrated brake system safety modeling, assessment of performance-based brake testing, and photonics in support of heavy truck safety. Other new research areas being considered include technologies to minimize truck rollover, vehicle dynamic modeling, and integrated truck safety inspection technologies.

National Aeronautics and Space Administration

ORNL continues to establish a visible presence in aerospace R&D and technology development and in relationships with NASA and its flight centers. Key R&D areas include space fission power, advanced power conversion and propulsion technology, advanced materials, and multi-megawatt reactor designs.

ORNL is a member of NASA's government team as part of DOE's effort to assist NASA in the planning and execution of a new program called Project Prometheus, which has the objective of developing nuclear-powered spacecraft to enable exploration of the outer solar system. This program was formerly called the Nuclear Systems Initiative. The space fission power portion of the program has two components: (1) a technology development program aimed at providing nuclear electric power and propulsion technologies and components such as reactor materials, power conversion equipment, ion thrusters, radiation-hard power electronics items, and autonomous control systems and (2) an initial mission designated the Jovian Icy Moon Orbiter (JIMO) project, which is being led by NASA's Jet Propulsion Laboratory. Initial technology development activities by DOE laboratories are being devoted to recapturing reactor materials technology, developing technical bases for the reactor and radiation shield components, developing autonomous reactor control technology, and establishing manufacturing processes and production capabilities for refractory materials, radiation shielding materials, and uranium nitride fuel. Within the technology development programs, ORNL is the lead DOE laboratory for materials technology development, with support from Y-12 on shield materials, and for autonomous reactor control. Initial JIMO activities are being devoted to conceptual studies, mission requirements development, and project planning. ORNL has roles in technical evaluation of reactor issues, conceptual design of radiation shields, designing and implementing the nuclear safety assurance program, development of a project strategy for logistics involving special nuclear materials, assessing the adequacy of the DOE

infrastructure to support the nuclear testing needs of the JIMO mission, and performing several programmatic support tasks involving work and infrastructure planning, National Environmental Policy Act (NEPA) compliance, and reactor cost estimating and scheduling.

ORNL is now supporting NASA's Radioisotope Power Systems (RPS) Program by producing clad vent sets of space-flight-quality iridium alloy for encapsulating the nuclear fuel pellets for the NASA New Horizons Program. This work will continue through at least FY 2005 and potentially longer. New Horizons is a new NASA scientific program to obtain the first reconnaissance of Pluto-Charon, a binary planet, and then multiple Kuiper Belt Objects (KBOs). New Horizons will seek to answer key scientific questions regarding the surfaces, atmospheres, interiors, and space environments of Pluto and Charon and KBOs using imaging, visible and infrared spectral mapping, ultraviolet spectroscopy, radio science, and in situ plasma sensors and will fly through the Pluto-Charon system as early as 2015. The production of the iridium alloys starts with pure iridium powder that is then alloyed by blending with other elements, compacted by sintering, and then melted to produce the metal alloy ingots. These ingots are extruded and then rolled to produce the high-quality sheet and foil material required for fabrication of clad vent sets.

Power conversion technologies for nuclear electric propulsion (NEP) enable outer solar system missions requiring propulsion far from the earth and enhance other such missions by reducing trip time, increasing payload, and providing ample power for scientific payloads. A major factor in achieving the performance targets is advances in power conversion technology. ORNL recently won a NASA research award entitled "Technology Development Program for an Advanced Potassium Rankine Power Conversion System Compatible with Several Space Reactor Designs." The objective of this program is to establish an optimized 100-kW(e) space-based Rankine power conversion system design by incorporating the latest material and component technology advances and will

- develop stainless steel and refractory metal space-based system designs that take advantage of material and component technology advances,
- optimize the cycle operating conditions and component/system masses, and
- address the key issue of zero-gravity two-phase fluid management by conducting a space flight experiment with a surrogate fluid.

We are working with NASA's George C. Marshall Space Flight Center in Huntsville, Alabama, to develop a breakthrough multi-megawatt space power reactor design methodology and a significantly improved multi-megawatt space power reactor concept. Evolutionary algorithm-based design approaches will be developed and applied to the design of a specific multi-megawatt space power reactor concept. The proposed effort is intended to

- develop and demonstrate a breakthrough methodology and tool for space reactor power system design,
- develop a conceptual design for an advanced, multi-megawatt space power reactor concept, and
- provide a platform for integration and evaluation of advanced technologies for improved terrestrial and space reactor power system concepts.

This effort is facilitated by Memoranda of Understandings (MOUs) established by DOE-ORO, linking DOE's Oak Ridge facilities to the Marshall Space Flight Center and the U.S. Air Force Arnold Engineering Development Center near Tullahoma, Tennessee. Through this Tri-Lateral Alliance, collaborations will be pursued in such areas as space fission power technology

development, advanced materials and material processes, environmental technology, remote sensing, robotics, space-based global change observation, space launch, and transportation technologies. We are also pursuing collaborations with NASA's Johnson Space Center and Glenn Research Center in the area of multi-megawatt space nuclear power system development for manned missions to Mars and beyond and advanced materials and space power conversion technology research.

ORNL also serves as NASA's Distributed Active Archive Center (DAAC) for Biogeochemical Dynamics for the Earth Observing System Data and Information System (EOSDIS). EOSDIS is part of NASA's contribution to the U.S. Global Change Research Program's effort to develop a predictive understanding of the global environment. Data from NASA and other sources archived at the ORNL DAAC are used to validate remote sensing land products and to parameterize and validate models of local, regional, and global-scale processes for projecting changes in the Earth's ecosystems. The ORNL DAAC also works closely with DOE's Carbon Dioxide Information Analysis Center at ORNL to archive and distribute data from measurement towers throughout the world. In order to promote the sharing of data and information, ORNL developed a modern Web-based system, Mercury (http://mercury.ornl.gov), to assist investigators in documenting data and making them available to users throughout the world. The ORNL DAAC uses Mercury for supporting field investigations in Brazil and Southern Africa, for validating remote sensing products, and for sharing a variety of earth sciences data from NASA- and U.S. Geological Survey (USGS)–funded centers across North America.

U.S. Environmental Protection Agency

ORNL's work for the EPA addresses numerous health and environmental problems and issues. Activities include evaluation of the cost-effectiveness of reducing nitrogen oxide emissions as a means of ozone control; involvement with EPA air quality research and modeling programs through the NARSTO Quality Systems Science Center [a Carbon Dioxide Information Analysis Center (CDIAC) program]; quality assurance and archiving of atmospheric chemistry and particulate matter data; development and testing of improvements to the ecological components of a multimedia model for air pollutants; development of tools, techniques, and guidance for performing Net Environmental Benefit Assessments, integrated risk assessments of on-site wastewater treatment systems, and radiological ecological risk assessments; evaluation of physiologically based pharmacokinetic models in risk assessment; preparation of literature reviews and chemical hazard information profiles for selected topics and chemicals; field validation of analysis methods under the Environmental Technology Verification Program; and development of reference dose profiles to reduce uncertainty in risk assessments. Research on mercury includes developing new methods for understanding the role of mercury speciation in the mercury re-emission process, developing and transferring technology to various states to assist in measuring mercury emissions from non-point sources, and understanding the fate of mercury in wastes applied to agricultural soils. For the Office of Pesticide Programs, critical evaluations of health, chemistry, and ecological data are performed in support of the registration and re-registration of pesticides. For the Office of Pollution Prevention and Toxics, Acute Exposure Guideline Levels are derived to provide guidance to emergency planners in the event of releases of chemicals, and assistance is provided to the High Production Chemical Volume Program, which is part of an international effort to better characterize the potential hazards of these chemicals.

U.S. Department of Health and Human Services

Our expectation is that the Complex Biological Systems Initiative will provide a systems biology resource for the National Institutes of Health (NIH), building on current NIH investments in mouse functional genomics and on developing NIH programs in proteomics, computational biology, biomedical technologies, and bioterrorism defense.

ORNL currently conducts research in bioanalytical chemistry (including development of advanced microfluidic devices and nanoscale arrays for molecular biology), biomedical engineering and bioimaging, biomaterials and biomimetics, genetics, functional genomics, proteomics (including advanced mass spectrometry development), and toxicology for the U.S. Department of Health and Human Services through various institutes of the NIH. Our research into the genetics of obesity is supported through a grant from the National Institute for Diabetes and Digestive and Kidney Diseases. Investigations of the genetics of germ cell susceptibility to environmental mutagenesis are supported by an interagency agreement with the National Institute of Environmental Health Sciences (NIEHS). Research was proposed to NIESH for linking human and ecological health risks by using sentinel wildlife species as indicators of human health effects. ORNL conducts research with the National Cancer Institute through a $2.4 million grant to develop a novel multi-spectral imaging system to provide a real-time in vivo identification and characterization of malignant tissues in the upper gastrointestinal tract. ORNL also conducts research for the National Heart, Lung, and Blood Institute; the National Institute on Aging; the National Institute of Biomedical Imaging and Bioengineering (NIBIB); the National Human Genome Research Institute; the National Institute for Mental Health; and the National Institute of General Medical Sciences.

ORNL will strengthen existing collaborations, form new collaborations, and serve as a resource to research groups at other national laboratories and in academia and industry. The Tennessee Mouse Genome Consortium (TMGC) pools expertise and resources for analyses of complex biological systems and promotes the mouse as a biomedical research model. It supports ORNL collaborations with Meharry Medical College, St. Jude Children's Research Hospital, the University of Memphis, the University of Tennessee (in Knoxville and Memphis), East Tennessee State University, and Vanderbilt University Medical Center, which provide ORNL with complementary capabilities (e.g., medical centers) and expertise. A 5-year grant from the NIH, which began in FY 2001 and supports the consortium's neuromutagenesis program, is being increased from $12.7 million to $13.7 million to cover expanded ORNL involvement.

The NIBIB provides support for staff from ORNL to be a liaison to NIBIB to assist in the development of programs and general support. Additionally, the Office of Biological and Environmental Research (OBER) provides support for ORNL to serve as a liaison to represent the Medical Sciences Division's interests and to assess programs in which both OBER and NIBIB may work together to form effective collaborations. The NIBIB also supports a 4-year $1.6 million grant to develop chemical nanosensing and actuation using mimetics at the cellular and molecular level.

The National Institute for Allergies and Infectious Diseases is expected to have a greatly expanded role in the U.S. defense against bioterrorism, starting in FY 2003. ORNL plans to support this effort by employing mice as a model to study effects of chemical, biological, and radiological threats. This research will make use of the new Laboratory for Comparative and Functional Genomics, construction of which is to be completed in FY 2003.

Genetic, reproductive, and general toxicology databases are developed, analyzed, and evaluated for the Food and Drug Administration (FDA), the National Library of Medicine, and the National Toxicology Program, with support from the Environmental Protection Agency (EPA). ORNL staff also provide the FDA Center for Food Safety and Applied Nutrition with critical evaluations of toxicology data for food additives.

A National AIDS/Cancer Match Registry developed at ORNL has been used throughout the world to identify tumor types developed in immuno-compromised individuals. The project is being repeated to determine the efficacy of AIDS-related drugs and to gain further insights into tumorigenesis.

The NIH National Cancer Institute has published the Atlas of Cancer Mortality for the United States, 1950–1994. The atlas shows the geographic patterns of cancer, opening the door for spatial analyses and research on cancer epidemiology and etiology. Establishing correlative spatial and temporal links between cancer incidence and mortality patterns is a critical task in establishing cancer etiology and enhancing cancer prevention. Research at ORNL focuses on developing spatial statistical methods and using geographical information systems to determine correlation among cancer types and a series of social, economic, and environmental factors at various spatial scales.

Federal Emergency Management Agency

ORNL programs for the Federal Emergency Management Agency (FEMA) include a range of R&D and technical assistance activities that support national preparedness for disasters and emergencies. ORNL serves as an independent center of expertise in areas that include emergency planning, training, exercises, simulation modeling, warnings, risk communication, sheltering, health effects, engineering assistance, analysis and assessment, and emergency evacuation procedures. ORNL has developed OREMS, the Oak Ridge Evacuation Modeling System, a state-of-the-art evacuation simulation system, for FEMA. ORNL has supported FEMA's Chemical Stockpile Emergency Preparedness Program (CSEPP) since 1989. In support of this program, ORNL has developed the CSEPP planning guidance, numerous training products, and a variety of technical studies. ORNL will continue to be a leader in developing technical training for that program and in providing analytical support in the areas of protective action decision making, sheltering-in-place, evacuation, and reentry into contaminated areas. Recently, ORNL has become involved in FEMA's Family and Community Preparedness Program and has been developing citizen preparedness information ("Are You Ready?") and state and local planning guides on warning systems and continuity of government. In addition, ORNL supports FEMA's international programs concerning information exchange and technology transfer.

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. This department also supports the development of economic models of various types, including models to predict which colleges and universities may experience relatively high levels of default on student loans.

- ORNL is collaborating with the U.S. Department of Agriculture (USDA) Office of Energy Policy and New Uses to incorporate data on potential energy crops into models of the agricultural sector used by USDA for economic and policy analyses. This work focuses on the FOLYSYS model developed and maintained for USDA by the University of Tennessee.
- ORNL serves the U.S. Agency for International Development as a center of expertise on energy planning, policy development, and renewable energy applications. Activities include research; analysis; technical assistance; project development, implementation, and evaluation; and information dissemination.
- ORNL scientists conduct environmental research in the Great Smoky Mountains National Park for the National Park Service.
- Support is provided to the Bureau of Labor Statistics in artificial intelligence systems to provide estimates of consumer prices index and survey automation.
- ORNL provides support in environmental management of water resources to several federal agencies. For example, ORNL staff serve as technical advisors to the U.S. Army Corps of Engineers on environmental issues such as hydropower impacts on fish and wildlife and instream flow policies and to the Northwest Power Planning Council and the Office of Science and Technology Policy on restoration of Pacific salmon.
- The U.S. Army Corps of Engineers provides support to develop economic models to assess the economic viability of improvements to the inland waterway system. In addition, economic models have been developed to (1) assess regional economic growth associated with an improved inland waterway system and (2) forecast future shipments of coal by barge on inland waterways.
- The U.S. Army National Guard provides support to develop economic models to predict the viability of establishing or enlarging National Guard facilities based on socioeconomic characteristics of selected communities.
- Sponsored by the interagency Strategic Environmental Research and Development Program (SERDP) and the DoD Environmental Security Technology Certification Program (ESTCP), ORNL is developing, demonstrating, validating, and applying technologies to a range of environmentally significant issues including unexploded ordnance detection and mapping, ecosystem management, land-use planning, threatened and endangered species protection, and hazardous material remediation. ORNL's activities address all the major SERDP/ESTCP thrust areas of Cleanup, Compliance, Conservation, Unexploded Ordnance, and Pollution Prevention.
- The National Institutes of Health support a variety of projects centered on mouse functional genomics and development of mass spectrometry, optical spectroscopy, and microfluidic "lab-on-a-chip" approaches for enhanced analysis of biological materials.
- Under the sponsorship of the interagency SERDP/ESTCP, ORNL staff are involved in an interagency group including DOE, DoD, the Agency for Toxic Substances and Disease Registry, and the EPA. The group's purpose is to improve the scientific methods and models for the performance and application of risk assessments. Ecological models developed at ORNL are used to address land management issues.
- The U.S. Geological Survey supports the development of regional and national data management and analysis tools as part of the National Biological Information Infrastructure program (NBII—Canada, the United States, and Mexico).

- ORNL designed and implemented the development of the NBII Data Clearinghouse for regional and national biological data management and analysis tools and will extend such support in 2003 to its sister program, the international Inter-American Biodiversity Information Network, which covers the entire Western Hemisphere.

Nonfederal Organizations

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

Private industry interacts with ORNL through cooperative R&D agreements, user agreements, licensing agreements, and other mechanisms. For example, ORNL supports the Idaho Power Company with environmental studies of how hydroelectric projects affect fish populations, an activity that complements other work for DOE's Hydropower Program. Sciex, an analytical instrumentation company, supports development of new ionization sources for mass spectrometers. Theragenics Corporation has designed and built an isotope production facility in the High Flux Isotope Reactor (HFIR). This facility will begin producing medical isotopes for cancer therapy this fall. Other private companies also use existing HFIR facilities for materials irradiation and isotope production (both for commercial and medical uses). A number of private companies use the neutron scattering facilities at the HFIR for research. 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, the Electric Power Research Institute, and Oak Ridge Associated Universities. States make use of ORNL expertise through agreements such as those with the State of Florida to study the environmental behavior of mercury; through the State Partnerships Program; and through user facility agreements, cooperative R&D agreements, and other mechanisms.

Supplemental Tables

Table S.1 presents projected resources (funding and direct personnel) by program. The projections in Table S.1 are based on funding requested in the FY 2004 budget submission documents, with some adjustments for subsequent guidance. The projections include some funding for construction that supports the major laboratory initiatives proposed in the Institutional Plan.

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

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

Table S.6 provides details on the use of ORNL's designated user facilities during FY 2002. Table S.7 provides details on participation in ORNL's university and science education programs.

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

	2002	2003	2004	2005	2006	2007	2008
Undersecretary for Energy, Science, and Environment							
Office of Science							
Fusion Energy Sciences—AT							
Total operating	18.2	19.4	19.2	20.7	21.2	23.9	28.7
Capital equipment	1.2	1.4	1.8	6.0	6.5	6.5	1.3
Total program	19.4	20.8	21.0	26.7	27.7	30.4	30.0
Total direct personnel (FTE)	59.7	63.7	64.1	60.9	63.0	65.2	67.5
Safeguards and Security Science—FS							
Total operating	4.6	6.7	6.5	6.6	6.6	6.1	6.3
Total direct personnel (FTE)	37.7	38.9	38.7	26.8	27.8	28.8	29.8
High Energy Physics—KA							
Total operating	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Capital equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total program	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Total direct personnel (FTE)	1.1	1.2	1.1	1.2	1.2	1.2	1.2
Nuclear Physics—KB							
Total operating	14.2	15.0	16.2	16.8	17.4	18.0	18.6
Capital equipment	1.4	1.4	1.7	2.8	2.9	3.8	3.9
Construction	0.4	0.4	0.4	0.4	0.0	0.0	0.0
Total program	16.0	16.8	18.3	19.9	20.3	21.7	22.4
Total direct personnel (FTE)	53.4	53.0	54.0	56.0	57.0	58.0	60.0
Basic Energy Sciences—KC							
Operating expense (excluding SNS)	87.4	87.3	88.9	92.0	104.7	104.7	104.7
Operating expense, SNS	15.0	15.0	19.8	35.0	34.5	150.4	150.2
Total operating	102.4	102.3	108.7	127.0	139.2	255.1	254.9
Capital equipment (excluding SNS)	9.1	7.7	5.9	11.1	11.1	11.1	11.5
Capital equipment, GPE[a] Landlord	1.9	2.6	2.9	3.2	3.3	3.4	3.5
Capital equipment, SNS	0.1	5.2	6.9	0.0	0.0	0.0	0.0
Construction (excluding SNS)	5.1	25.6	20.0	17.8	0.0	0.0	0.0
Construction, GPP[b] Landlord	4.2	5.4	5.7	6.5	7.2	7.8	7.8
Construction, SNS	276.3	210.6	124.6	79.8	41.1	0.0	0.0
Proposed construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total program	399.1	359.4	274.7	245.4	201.9	277.4	277.8
Total direct personnel (FTE)	600.5	594.0	626.0	655.0	722.0	790.0	798.0
Energy Research Analyses—KD							
Total operating	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel (FTE)	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Multiprogram Energy Laboratories—Facilities Support—KG							
Total operating	0.0	2.2	2.0	2.1	2.1	2.2	2.3
Capital equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	7.6	9.8	9.6	2.8	18.8	3.0	0.0
Proposed construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total program	7.6	12.0	11.6	4.9	20.9	5.3	2.3
Total direct personnel (FTE)	11.7	21.0	23.6	7.2	20.2	16.7	5.2
Facilities and Infrastructure—KH							
Total operating	3.1	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	3.3	0.0	0.0	0.0	0.0	0.0	0.0
Computational and Technology Research—KJ							
Total operating	26.7	25.3	26.4	27.3	28.3	29.2	30.3
Capital equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total program	26.7	27.3	26.4	27.3	28.3	29.2	30.3
Total direct personnel (FTE)	38.5	42.0	52.5	53.5	54.5	55.0	56.0

Table S.1 (continued)

	2002	2003	2004	2005	2006	2007	2008
Biological and Environmental Research—KP							
Total operating	37.3	44.1	43.9	45.5	47.1	48.7	50.4
Capital equipment	5.1	1.2	2.1	0.1	0.1	0.1	0.1
Construction	11.4	0.0	0.0	0.0	0.0	0.0	0.0
Total program	53.8	45.3	46.1	45.6	47.2	48.9	50.6
Total direct personnel (FTE)	100.9	102.0	102.0	100.0	100.0	100.0	100.0
Total Office of Science							
Operating expense	207.3	215.5	223.6	246.6	262.5	384.0	392.2
Capital equipment	16.9	15.4	13.2	20.0	20.6	21.5	16.8
Capital equipment, GPE Landlord	1.9	2.6	2.9	3.2	3.3	3.4	3.5
Capital equipment, SNS	0.1	5.2	6.9	0.0	0.0	0.0	0.0
Construction (excluding SNS)	27.4	35.8	30.0	21.0	18.8	3.0	0.0
Construction, GPP Landlord	4.2	5.4	5.7	6.5	7.2	7.8	7.8
SNS construction	276.3	210.6	124.6	79.8	41.1	0.0	0.0
Proposed construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total program	534.1	490.5	406.9	377.1	353.5	419.7	420.4
Total direct personnel (FTE)	906.9	915.8	962.0	960.6	1045.6	1114.9	1117.6
Office of Energy Efficiency and Renewable Energy							
Solar and Renewable Resource Technologies—EB							
Total operating	18.5	20.0	20.6	21.3	22.0	22.8	23.6
Capital equipment	0.0	(0.0)	2.3	2.9	0.5	0.5	0.5
Total program	18.5	20.0	24.3	38.6	22.5	23.3	24.1
Total direct personnel (FTE)	44.1	41.7	51.4	55.1	51.8	53.5	55.4
Buildings Sector—EC							
Total operating	13.1	11.5	12.5	12.3	12.8	13.2	13.7
Capital equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total program	13.1	11.5	12.5	12.3	12.8	13.2	13.7
Total direct personnel (FTE)	38.4	31.5	32.5	33.6	34.8	36.0	37.3
Industrial Sector—ED							
Total operating	15.7	17.8	17.9	18.6	19.2	19.9	20.6
Capital equipment	0.9	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total program	16.6	17.8	17.9	18.6	19.2	19.9	20.6
Total direct personnel (FTE)	41.0	38.9	39.7	38.0	39.8	41.6	44.1
Transportation Sector—EE							
Total operating	40.0	42.1	43.7	45.3	46.9	48.5	50.2
Capital equipment	0.5	0.2	0.0	0.0	0.0	0.0	0.0
Total program	40.5	42.2	43.7	45.3	46.9	48.5	50.2
Total direct personnel (FTE)	100.6	110.0	114.2	111.5	113.2	117.3	121.9
Policy and Management—EH							
Total operating	0.8	0.4	0.5	0.5	0.5	0.6	0.6
Total direct personnel (FTE)	2.9	1.8	1.6	1.7	1.1	1.8	1.9
Federal Energy Management Program—EL							
Total operating	3.7	4.3	4.5	4.6	4.8	4.9	5.1
Total direct personnel (FTE)	15.4	16.8	17.2	18.5	18.9	19.6	20.0
Power Technologies—EO							
Total operating	27.0	28.0	29.0	30.0	31.0	32.1	33.3
Total direct personnel (FTE)	23.7	27.2	29.3	32.1	33.3	34.5	35.7
In-House Energy Management—WB							
Total operating	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel (FTE)	0.3	0.0	0.0	0.0	0.0	0.0	0.0

Table S.1 (continued)

	2002	2003	2004	2005	2006	2007	2008
Total Office of Energy Efficiency and Renewable Energy							
Operating expense	118.8	124.0	128.7	132.6	137.2	142.0	147.0
Capital equipment	1.4	0.1	2.3	2.9	0.5	0.5	0.5
Proposed construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total program	120.2	124.2	132.4	149.9	137.7	142.5	147.5
Total direct personnel (FTE)	266.3	267.9	285.7	290.6	293.5	304.5	316.3
Office of Nuclear Energy, Science and Technology							
Nuclear Energy R&D—AF							
Total operating	10.4	21.1	16.6	25.8	26.6	27.4	28.2
Capital equipment	0.0	0.4	0.8	0.8	0.9	0.9	0.9
Construction	0.0	0.0	3.0	1.5	0.0	0.0	0.0
Total program	10.4	21.5	20.4	28.1	27.5	28.3	29.1
Total direct personnel (FTE)	29.1	57.1	76.9	67.2	63.8	63.6	63.7
Uranium Enrichment—CD							
Total operating	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel (FTE)	0.9	0.0	0.0	0.0	0.0	0.0	0.0
Program Direction—Nuclear Energy—KK							
Total operating	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel (FTE)	0.1	0.0	0.0	0.0	0.0	0.0	0.1
Isotope Production and Distribution Program—ST							
Total operating	11.1	9.0	9.0	9.3	9.6	10.0	10.3
Capital equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total program	11.1	9.0	9.0	9.3	9.6	10.0	10.3
Total direct personnel (FTE)	30.5	26.8	26.7	27.6	28.6	29.6	30.6
Total Office of Nuclear Energy, Science and Technology							
Operating expense	21.5	30.1	25.6	35.1	36.2	37.4	38.5
Capital equipment	0.0	0.4	0.8	0.8	0.9	0.9	0.9
Construction	0.0	0.0	3.0	1.5	0.0	0.0	0.0
Total program	21.5	30.5	29.4	37.5	37.1	38.3	39.5
Total direct personnel (FTE)	60.7	83.9	103.6	94.9	92.5	93.3	94.4
Office of Fossil Energy							
Coal—AA							
Total operating	9.2	9.0	10.7	11.1	11.5	11.9	12.3
Total direct personnel (FTE)	19.6	20.8	23.7	26.9	26.9	27.8	29.2
Gas—AB							
Total operating	0.9	0.5	0.3	0.3	0.3	0.3	0.3
Total direct personnel (FTE)	1.7	2.3	0.8	0.6	0.6	0.6	0.6
Petroleum—AC							
Total operating	2.0	2.0	1.6	1.7	1.7	1.8	1.8
Total direct personnel (FTE)	7.9	7.2	7.2	5.4	5.4	5.4	5.8
Innovative Clean Coal Technology—AZ							
Total operating	0.3	0.1	0.3	0.3	0.3	0.3	0.3
Total direct personnel (FTE)	0.6	0.9	1.5	1.0	1.0	1.1	1.1
Strategic Petroleum Reserve—SA							
Total operating	0.2	0.4	0.4	0.4	0.4	0.4	0.4
Total direct personnel (FTE)	0.8	0.8	0.9	1.0	1.0	1.0	1.1
Total Office of Fossil Energy							
Total operating	12.6	11.9	13.2	13.6	14.1	14.6	15.1
Total direct personnel (FTE)	30.6	32.0	34.3	34.9	34.9	36.0	37.7

Table S.1 (continued)

	2002	2003	2004	2005	2006	2007	2008
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 direct personnel (FTE)	0.4	0.1	0.1	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
Total direct personnel (FTE)	0.4	0.1	0.1	0.0	0.0	0.0	0.0
Office of Environmental Management							
Environmental Management—EM (ORNL Financial Plan)							
Total operating	30.9	9.4	12.1	12.1	12.1	12.1	12.1
Capital equipment	(0.1)	0.0	0.0	0.0	0.0	0.0	0.0
Total program	29.9	9.4	12.1	12.1	12.1	12.1	12.1
Total direct personnel (FTE)	95.3	40.0	39.1	40.3	41.7	43.2	44.7
Total Office of Environmental Management							
Total operating	30.9	9.4	12.1	12.1	12.1	12.1	12.1
Capital equipment	(1.0)	0.0	0.0	0.0	0.0	0.0	0.0
Total program	29.9	9.4	12.1	12.1	12.1	12.1	12.1
Total direct personnel (FTE)	95.3	40.0	39.1	40.3	41.7	43.2	44.7
Office of Civilian Radioactive Waste Management							
Nuclear Waste Fund—DF							
Total operating	0.1	0.2	0.5	0.5	0.5	0.6	0.6
Total direct personnel (FTE)	0.2	1.0	2.4	2.5	2.6	2.7	2.8
Total Office of Civilian Radioactive Waste Management							
Total operating	0.1	0.2	0.5	0.5	0.5	0.6	0.6
Total direct personnel (FTE)	0.2	1.0	2.4	2.5	2.6	2.7	2.8
Undersecretary for National Nuclear Security							
Office of the Deputy Administrator for National Nuclear Security							
Naval Reactors—AJ							
Total operating	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total direct personnel (FTE)	0.5	0.4	0.4	0.4	0.5	0.5	0.5
Weapons Activities—DP							
Total operating	21.4	17.3	20.7	20.7	21.5	22.2	23.0
Capital equipment	0.5	0.2	0.1	0.4	0.2	0.2	0.2
Proposed construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total program	21.9	17.2	20.8	21.1	21.6	22.4	23.1
Total direct personnel (FTE)	71.2	81.3	84.3	83.3	82.7	85.5	88.5
Defense Nuclear Nonproliferation—NN							
Total operating	106.7	71.6	68.8	71.2	73.7	76.3	78.9
Capital equipment	1.5	0.3	(0.5)	0.0	0.0	0.0	0.0
Total program	108.2	71.9	68.3	71.2	73.7	76.3	78.9
Total direct personnel (FTE)	78.2	84.0	88.5	93.1	98.0	92.8	84.7
Total Deputy Administrator for National Nuclear Security							
Total operating	128.2	88.9	89.5	92.0	95.2	98.6	102.0
Capital equipment	2.0	0.4	(0.4)	0.4	0.2	0.2	0.2
Construction	0.0	(0.2)	0.0	0.0	0.0	0.0	0.0
Total program	130.2	89.1	89.1	92.4	95.4	98.7	102.2
Total direct personnel (FTE)	149.9	165.7	173.2	176.9	181.1	178.8	173.6
Departmental Staff and Support Offices							
Office of Environment, Safety and Health							
Environment, Safety, and Health—HA							
Total operating	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Total direct personnel (FTE)	0.0	1.1	0.0	0.0	0.0	0.0	0.0

Table S.1 (continued)

	2002	2003	2004	2005	2006	2007	2008
Environment, Safety, and Health (Non-Defense)—HC							
Total operating	1.4	1.2	1.5	1.6	1.6	1.7	1.7
Total direct personnel (FTE)	5.0	5.1	6.0	6.1	6.2	6.3	6.3
Environment, Safety, and Health (Defense)—HD							
Total operating	1.0	0.6	0.6	0.6	0.6	0.6	0.6
Total direct personnel (FTE)	2.5	2.6	2.3	2.1	1.9	2.1	1.9
Total Office of Environment, Safety, and Health							
Total operating	2.5	1.8	2.1	2.1	2.2	2.3	2.4
Total direct personnel (FTE)	7.5	8.7	8.3	8.2	8.1	8.4	8.3
Office of Counterintelligence							
Counterintelligence—CN							
Total operating	1.3	1.3	1.8	1.8	1.8	1.8	1.8
Total direct personnel (FTE)	8.1	9.3	9.7	0.0	0.0	0.0	0.0
Total Office of Counterintelligence							
Total operating	1.3	1.3	1.8	0.0	0.0	0.0	0.0
Total direct personnel (FTE)	8.1	9.3	9.7	0.0	0.0	0.0	0.0
Office of Intelligence							
Intelligence—IN							
Total operating	0.0	0.2	0.2	0.2	0.2	0.2	0.2
Total direct personnel (FTE)	0.0	1.0	1.0	1.0	1.0	1.0	1.0
Total Office of Intelligence							
Total operating	0.0	0.2	0.2	0.2	0.2	0.2	0.2
Total direct personnel (FTE)	0.0	1.0	1.0	1.0	1.0	1.0	1.0
Office of Security and Emergency Operations							
Nuclear Safeguards and Security—GD							
Total operating	0.1	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	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Total direct personnel (FTE)	0.2	0.3	0.2	0.2	0.2	0.2	0.2
Office of Security and Emergency Management							
Total operating	0.0	0.0	0.1	0.1	0.1	0.1	0.1
Total direct personnel (FTE)	0.0	0.1	0.2	0.2	0.2	0.2	0.2
Total Office of Security and Emergency Operations							
Total operating	0.1	0.2	0.2	0.2	0.2	0.2	0.3
Total direct personnel (FTE)	0.3	0.4	0.4	0.4	0.4	0.5	0.5
Office of the Chief Information Officer							
Cyber Security—CS							
Total operating	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel (FTE)	0.5	0.8	0.0	0.0	0.0	0.0	0.0
Total Office of the Chief Information Officer							
Total operating	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel (FTE)	0.5	0.8	0.0	0.0	0.0	0.0	0.0
Office of Policy and International Affairs							
International Affairs—IA							
Total operating	0.0	(0.0)	0.0	0.0	0.0	0.0	0.0
Total direct personnel (FTE)	0.1	0.2	0.0	0.0	0.0	0.0	0.0
Policy, Analysis, and Systems Studies—PE							
Total operating	0.2	0.1	0.2	0.2	0.2	0.3	0.3
Total direct personnel (FTE)	0.8	0.8	0.7	0.7	0.7	0.8	0.8
Total Office of Policy and International Affairs							
Total operating	0.2	0.1	0.2	0.2	0.2	0.3	0.3
Total direct personnel (FTE)	0.6	0.7	0.5	0.5	0.7	0.8	0.8

Table S.1 (continued)

	2002	2003	2004	2005	2006	2007	2008
Office of Hearings and Appeals							
General Administration Program Direction—WA							
Total operating	0.1	0.0	(0.0)	0.0	0.0	0.0	0.0
Total direct personnel (FTE)	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Total Office of Hearings and Appeals							
Total operating	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel (FTE)	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Office of Worker and Community Transition							
Worker and Community Transition Program—GG							
Total operating	0.0	(0.3)	0.0	0.0	0.0	0.0	0.0
Total direct personnel (FTE)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Office of Worker and Community Transition							
Total operating	0.0	(0.3)	0.0	0.0	0.0	0.0	0.0
Total direct personnel (FTE)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Federal Energy Regulatory Commission							
Federal Energy Regulatory Commission—VR							
Total operating	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel (FTE)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Federal Energy Regulatory Commission							
Total operating	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel (FTE)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Environmental Management (Bechtel Jacobs Company LLC)							
Total operating	13.2	12.9	11.8	10.1	10.4	10.7	11.0
Total direct personnel (FTE)	21.1	20.5	19.4	16.6	17.1	17.5	18.1
Subtotal DOE Programs							
Total operating	537.0	496.3	509.5	547.2	573.0	704.6	723.4
Capital equipment (excluding SNS)	19.3	16.3	15.9	24.0	22.1	23.1	18.4
Capital equipment, SNS	0.1	5.2	6.9	0.0	0.0	0.0	0.0
Capital equipment, GPE Landlord	1.9	2.6	2.9	3.2	3.3	3.4	3.5
Construction (excluding SNS)	27.4	35.6	34.5	37.0	18.8	3.0	0.0
Construction, GPP Landlord	4.2	5.4	5.7	6.5	7.2	7.8	7.8
SNS construction	276.3	210.6	124.6	79.8	41.1	0.0	0.0
Proposed construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	866.2	772.0	700.0	697.7	665.5	741.9	753.2
Total direct personnel (FTE)	1548.7	1548.1	1639.7	1627.4	1719.3	1801.3	1815.8
DOE Contractors and Operations Offices							
Total operating	58.6	36.3	33.4	24.4	24.8	25.6	26.2
Total direct personnel (FTE)	129.9	130.1	97.6	63.4	65.3	67.0	68.4
Cooperative R&D Agreements							
Total operating	6.6	7.0	7.4	7.7	7.9	8.2	8.5
Total direct personnel (FTE)	23.4	30.8	29.0	29.7	30.8	30.8	31.9
Total DOE Programs							
Total operating	602.2	539.5	550.3	579.3	605.8	738.4	758.1
Capital equipment (excluding SNS)	19.3	16.3	15.9	24.0	22.1	23.1	18.4
Capital equipment, GPE Landlord	1.9	2.6	2.9	3.2	3.3	3.4	3.5
Capital equipment, SNS	0.1	5.2	6.9	0.0	0.0	0.0	0.0
Construction (excluding SNS)	27.4	35.6	34.5	37.0	18.8	3.0	0.0
Construction, GPP Landlord	4.2	5.4	5.7	6.5	7.2	7.8	7.8
SNS construction	276.3	210.6	124.6	79.8	41.1	0.0	0.0
Proposed construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	931.4	815.3	740.8	729.8	698.3	775.7	787.9
Total direct personnel (FTE)	1702.0	1709.1	1766.3	1720.5	1815.4	1899.2	1916.1

Table S.1 (continued)

	2002	2003	2004	2005	2006	2007	2008
Work for Others							
Nuclear Regulatory Commission							
Total operating expense	9.7	10.7	12.1	12.5	12.8	13.0	13.3
Total direct personnel (FTE)	24.0	34.8	38.1	38.3	38.3	38.3	38.3
Department of Defense							
Total operating expense	39.9	54.8	48.4	42.3	43.7	45.3	46.8
Total direct personnel (FTE)	89.2	133.6	143.0	115.6	119.7	123.9	128.2
National Aeronautics and Space Administration							
Total operating expense	5.3	8.9	14.4	14.4	14.4	14.4	14.4
Total direct personnel (FTE)	14.1	28.3	46.2	47.5	47.5	47.5	47.5
Department of Health and Human Services							
Total operating expense	1.6	0.8	2.1	2.2	2.3	2.4	2.5
Total direct personnel (FTE)	5.4	6.1	5.9	6.1	6.3	6.5	6.7
Environmental Protection Agency							
Total operating expense	3.9	4.2	4.9	5.1	5.3	5.5	5.7
Total direct personnel (FTE)	17.3	17.4	21.3	22.0	20.6	20.9	21.7
Federal Emergency Management Agency							
Total operating expense	1.2	0.9	0.9	0.9	0.9	0.9	0.9
Total direct personnel (FTE)	3.1	3.1	3.0	2.8	2.8	2.8	2.8
Department of Transportation							
Total operating expense	5.1	3.5	3.1	3.2	3.3	3.4	3.6
Total direct personnel (FTE)	15.4	16.1	9.5	8.0	8.3	8.6	8.9
Other Federal agencies							
Total operating expenses	4.8	4.9	5.1	5.3	5.4	5.6	5.7
Total direct personnel (FTE)	8.2	13.1	11.5	11.2	11.4	11.1	10.4
Electric Power Research Institute							
Total operating	0.6	0.2	0.2	0.2	0.2	0.2	0.2
Total direct personnel (FTE)	1.9	2.3	0.5	0.1	0.1	0.1	0.1
Other nonfederal agencies							
Total operating expense	13.7	14.1	15.4	16.0	16.6	17.3	18.0
Total direct personnel (FTE)	43.2	54.8	51.5	53.9	55.7	56.8	59.1
Total Work for Others							
Total operating expense	85.8	102.9	106.7	102.0	104.9	108.0	111.0
Total direct personnel (FTE)	221.4	309.9	330.6	305.6	310.7	316.5	323.9
Total Program Resources							
Total operating expense	688.0[c]	642.4	657.0	681.3	710.7	846.4[d]	869.2
Capital equipment (excluding SNS)	19.3	16.3	15.9	24.0	22.1	23.1	18.4
Capital equipment, SNS	0.1	5.2	6.9	0.0	0.0	0.0	0.0
Capital equipment, GPE Landlord	1.9	2.6	2.9	3.2	3.3	3.4	3.5
Construction (excluding SNS)	27.4	35.6	34.5	37.0	18.8	3.0	0.0
Construction, GPP Landlord	4.2	5.4	5.7	6.5	7.2	7.8	7.8
SNS construction	276.3	210.6	124.6	79.8	41.1	0.0	0.0
Proposed construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	1017.2	918.2	847.4	831.8	803.2	883.7	898.9
Total direct personnel (FTE)	1923.3	2019.0	2096.9	2026.0[e]	2126.1	2215.7	2239.9

[a]GPE = General Plant Equipment.
[b]GPP = General Plant Project.
[c]NN program funding moved from Y-12 to ORNL.
[d]SNS comes online.
[e]DOD conservative estimate.

Table S.2. Equal Employment Opportunity statistics for FY 2002

Occupational Code	Total (%)[a]		Black (%)		Hispanic (%)		Native American/ Alaskan Native (%)		Asian/Pacific Islander (%)		Minority total (%)		White (%)	
	M[b]	F[c]	M	F	M	F	M	F	M	F	M	F	M	F
Officials and managers[d]	365 (83.3)	73 (16.7)	17 (3.9)	1 (0.2)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	8 (1.8)	3 (0.7)	25 (5.7)	4 (0.9)	340 (77.6)	69 (15.8)
Professionals	1531 (77.4)	446 (22.6)	37 (1.9)	25 (1.3)	27 (1.4)	5 (0.3)	1 (0.1)	1 (0.1)	97 (4.9)	26 (1.3)	162 (8.2)	57 (2.9)	1369 (69.2)	389 (19.7)
Technicians	251 (69.7)	109 (30.3)	8 (2.2)	8 (2.2)	5 (1.4)	1 (0.3)	0 (0.0)	1 (0.3)	1 (0.3)	1 (0.3)	14 (3.9)	11 (3.1)	237 (65.8)	98 (27.2)
Clerical	19 (3.9)	463 (96.1)	4 (0.8)	49 (10.2)	0 (0.0)	2 (0.4)	0 (0.0)	1 (0.2)	0 (0.0)	6 (1.2)	4 (0.8)	58 (12.0)	15 (3.1)	405 (84.0)
Crafts	337 (96.8)	11 (3.2)	22 (6.3)	0 (0.0)	1 (0.3)	0 (0.0)	0 (0.0)	0 (0.0)	2 (0.6)	0 (0.0)	25 (7.2)	0 (0.0)	312 (89.7)	11 (3.2)
Operators	47 (81.0)	11 (19.0)	2 (3.4)	1 (1.7)	0 (0.0)	0 (0.0)	0 (0.0)	1 (1.7)	0 (0.0)	0 (0.0)	2 (3.4)	2 (3.4)	45 (77.6)	9 (15.5)
Laborers	60 (69.0)	27 (31.0)	22 (25.3)	11 (12.6)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	22 (25.3)	11 (12.6)	38 (43.7)	16 (18.4)
Service workers	83 (71.6)	33 (28.4)	13 (11.2)	11 (9.5)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.9)	0 (0.0)	2 (1.7)	13 (11.2)	14 (12.1)	70 (60.3)	19 (16.4)
Total	2693 (69.7)	1173 (30.3)	125 (3.2)	106 (2.7)	33 (0.9)	8 (0.2)	1 (0.0)	5 (0.1)	108 (2.8)	38 (1.0)	267 (6.9)	157 (4.1)	2426 (62.8)	1016 (26.3)

[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).

Table S.3. ORNL staff composition (as of September 30, 2002)[a]

	Ph.D.	M.S.	B.S./B.A.	Other	Total
Professional staff					
Scientists	437	155	116	37	745
Engineers	271	205	174	75	725
Management/administrative	106	292	329	217	944
Support staff					
Technicians	0	6	72	282	360
All other	0	6	78	1008	1092
Total ORNL staff	814	664	769	1619	3866

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

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

	2000[a]	2001[a]	2002[a]	2003	2004
Universities					
SNS	0.1	0.0	0.0	0.0	0.0
ORNL excluding SNS	22.7	24.5	23.9	20.0	21.0
All others					
SNS	55.7	88.6	117.2	92.2	36.0
ORNL excluding SNS	135.3	151.3	228.6	237.1	249.0
Transfers to other DOE facilities					
SNS	0.0	0.0	0.0	0.0	0.0
ORNL excluding SNS	0.8	1.3	1.5	2.0	2.0
Total external subcontracts and procurements					
SNS	55.8	88.6	117.2	92.2	36.0
ORNL excluding SNS	158.8	177.1	254.0	259.1	272.0

[a]Actual.

Table S.5. Estimated small and disadvantaged business procurement
(by fiscal year)

	2000[a]	2001[a]	2002[a]	2003
Total small and disadvantaged business procurement, in millions of dollars				
SNS	6.2	9.1	21.0	18.1
ORNL (excluding SNS)	63.3	68.3	91.4	105.0
Small and disadvantaged business procurement, as a percentage of total procurement				
SNS	11.0	10.3	17.9	19.6
ORNL (excluding SNS)	39.9	38.4	36.0	40.0

[a]Actual.

Table S.6. Experimenters at ORNL's designated user facilities in FY 2002[a,b]

	Number of experimenters	Non-ORNL organizations
Bioprocessing Research and Development Center		
ORNL	0	—
Other U.S. government laboratories	0	0
U.S. universities	6	2
U.S. industry	2	2
International organizations	0	0
Total	**8**	**4**
Buildings Technology Center		
ORNL	0	—
Other U.S. government laboratories	1	1
U.S. universities	0	0
U.S. industry	46	33
International organizations	0	0
Total	**47**	**34**
Californium User Facility for Neutron Sciences		
ORNL	1	—
Other U.S. government laboratories	1	1
U.S. universities	1	1
U.S. industry	0	0
International organizations	0	0
Total	**3**	**2**
High Flux Isotope Reactor		
ORNL	29	—
Other U.S. government laboratories	0	0
U.S. universities	8	3
U.S. industry	37	33
International organizations	2	2
Total	**76**	**38**
High Temperature Materials Laboratory		
ORNL	14	—
Other U.S. government laboratories	7	4
U.S. universities	407	165
U.S. industry	194	103
International organizations	0	0
Total	**622**	**272**
Holifield Radioactive Ion Beam Facility		
ORNL	24	—
Other U.S. government laboratories	26	3
U.S. universities	77	27
U.S. industry	0	0
International organizations	17	15
Total	**144**	**45**
Metals Processing Laboratory User Facility (MPLUS)		
ORNL	1431	—
Other U.S. government laboratories	14	1
U.S. universities	130	5
U.S. industry	1287	44
International organizations	0	0
Total	**2862**	**50**

Table S.6 (continued)

	Number of experimenters	Non-ORNL organizations
Mouse Genetic Research Facility		
ORNL	0	—
Other U.S. government laboratories	0	0
U.S. universities	20	15
U.S. industry	0	0
International organizations	0	0
Total	**20**	**15**
Oak Ridge National Environmental Research Park[c]		
ORNL	35	—
Other U.S. government laboratories	31	5
U.S. universities	143	19
U.S. industry	0	0
International organizations	1	1
State and educational agencies	81	12
Total	**291**	**37**
Physical Properties Research Facility		
ORNL	0	—
Other U.S. government laboratories	0	0
U.S. universities	0	0
U.S. industry	0	0
International organizations	60	1
Total	**60**	**1**
Shared Research Equipment (SHaRE) Facility		
ORNL	68	—
Other U.S. government laboratories	82	10
U.S. universities	52	27
U.S. industry	1	15
International organizations	6	5
Total	**209**	**57**

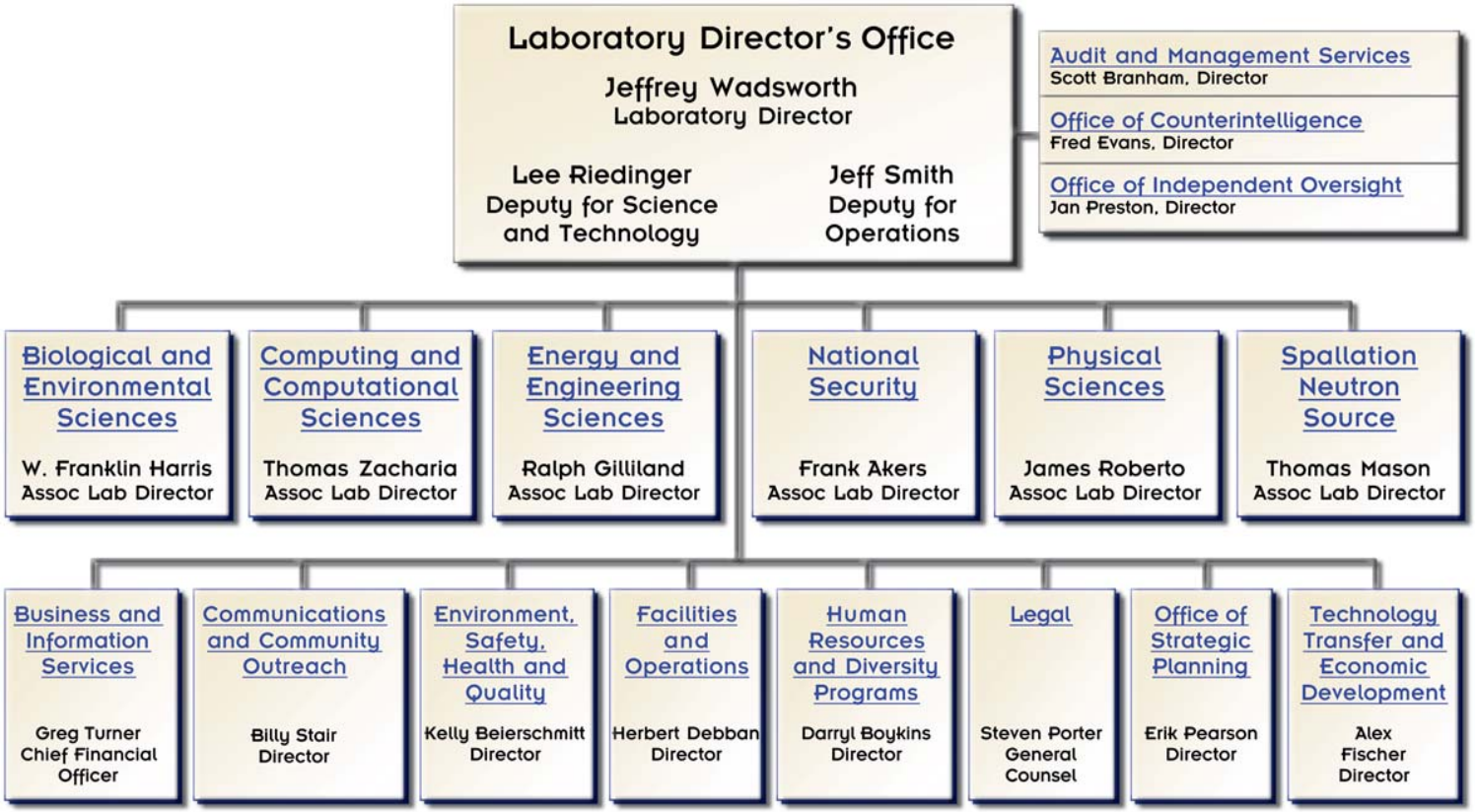
[a]The following designated new user facilities did not have any experimenters: Computational Center for Industrial Innovation; Cooling, Heating, and Power Integration Laboratory; Fuels, Engines, and Emissions Research Center; National Transportation Research Center; and Power Electronics and Electric Machinery. The Oak Ridge Electron Linear Accelerator (ORELA), established in 1969, was shut down for the entire CY 2002.

[b]Statistics for U.S. government laboratories do not include undergraduate students (if any); statistics for international organizations include users from foreign institutions, regardless of citizenship.

[c]Totals do not include approximately 4606 individuals who participated in the Ecological and Physical Sciences Study Center and High School Honors Program.

Table S.7. University and science education statistics

	FY 2002		
	Total	Minorities	Women
Precollege student programs			
Appalachian Regional Commission Honors Academy	35	4	21
Science Explorers Camp	30	4	16
Ecological and Physical Sciences Study Center	4606	414	2503
Precollege teacher programs			
Appalachian Regional Commission Teacher Leadership Institute	17	1	12
Undergraduate programs			
Energy Research Undergraduate Laboratory Fellowships	79	15	27
Great Lakes Colleges Association / Associated Colleges of the Midwest Science Semester	6	1	3
Community College Initiative	10	4	4
HERE@ORNL	98	55	45
Pre-Service Teachers	6	0	4
Graduate programs			
HERE@ORNL	38	21	18
Postgraduate programs			
DOE Postdoctoral Programs	170	81	37
Faculty programs			
HERE@ORNL Faculty Research	18	5	6
Great Lakes Colleges Association / Associated Colleges of the Midwest	1	0	0
Minority Educational Institutes Faculty Research	11	7	1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