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Oak Ridge National Laboratory
Institutional Plan
FY 1995–FY 2000

November 1994

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Contents

1 • Laboratory Director's Statement

There is an ancient Chinese expression that has apparently been visited upon the U.S. Department of Energy and its national laboratories: "May you live in interesting times." Certainly 1994—a year that has brought a new task force charged with examining the future of the Department's national laboratories, a new vision and mission for the Department, and a new articulation of the nation's goals and strategies for science—qualifies for this definition, and the years ahead promise to be no less interesting for the Oak Ridge National Laboratory (ORNL).

The Secretary of Energy Advisory Board Task Force on Alternative Futures for the Department of Energy National Laboratories—quickly rechristened "the Galvin Task Force" in honor of its chairman, Robert Galvin, and in the interest of brevity—was created in February 1994. It was charged with examining options for change within the Department's multiprogram national laboratories and proposing specific alternatives for redirecting their resources toward national needs.

In preparation for the scrutiny of the Galvin Task Force, ORNL identified several areas to be addressed: validation of core competencies, determination of the best organizational structure for ORNL, self-evaluation against the criteria for the Malcolm Baldrige National Quality Award, and exploration of opportunities for cost reduction. It was soon recognized that these activities would be of continuing value "beyond Galvin," and the commitment to excellence that they embody is an integral part of ORNL's activities and planning.

In April 1994, the Department of Energy announced its mission and vision in a new strategic plan.* The product of a comprehensive planning process that involved Department employees, the national laboratories, and others interested in the Department's future, this plan describes "a massive reshaping" of the Department's goals, priorities, and business practices.

ORNL contributed to the development of the Department's strategic plan and is working to align its activities with the five business lines defined in the plan: science and technology, energy resources, environmental quality, industrial competitiveness, and national security. ORNL is also committed to integrating into its activities the four critical success factors identified by the Department: communication and trust; human resources; environment, safety, and health; and management practices. The strategic plan that appears in Sect. 3 of this document reflects these efforts; like the Department's strategic plan, it is a work in progress, evolving in response to new challenges and new opportunities as they arise.

**Fueling a Competitive Economy: Strategic Plan,* DOE/S-0108, U.S. Department of Energy, April 1994.

In August 1994, the White House issued a policy statement titled *Science in the National Interest.** This document sets five goals: maintaining leadership across the frontiers of scientific knowledge, enhancing connections between fundamental research and national goals, stimulating partnerships that promote investment in fundamental science and engineering and effective use of resources, producing the finest scientists and engineers for the twenty-first century, and raising the scientific and technological literacy of all Americans. It concludes with a call for a shared commitment to common goals and to excellence.

As a national laboratory, ORNL is uniquely positioned to support these national goals, which are echoed in the strategic plans of the Department and the Laboratory. ORNL is already conducting leading-edge research across a broad range of inquiry; integrating fundamental research, applied research, and technology development; building and participating in partnerships with industry, universities, other federal agencies, and other nations; educating the next generation of scientists and engineers; and sharing information about science and technology. The major initiatives that ORNL is pursuing—the Advanced Neutron Source, the Center for Biological Sciences, and the Advanced Materials Science and Engineering Complex—also reflect and support these goals.

- The Advanced Neutron Source, ORNL's top scientific priority for the future, will be a peerless facility for probing the structure of matter in the fields of material science, biology, polymer science, chemistry, and solid-state physics.
- The Center for Biological Sciences will strengthen and extend a broad program of research and development that is investigating the mechanisms of human genetic development, exploring the building blocks of life at the molecular level, and creating and deploying innovative applications of biotechnology in fields ranging from medicine to energy production.
- The Advanced Materials Science and Engineering Complex will foster the development of the understanding of materials and materials-related processes and phenomena, from atomic structure to macroscopic properties, that is necessary both to underpin energy technologies and industrial endeavors and to ensure the nation's continued economic competitiveness in these crucial areas.

The Galvin Task Force recently asked the directors of the Department of Energy's laboratories for their thoughts on the future of these institutions. The consensus of this group is that the Department and its laboratories can provide much of the science and technology base needed for achieving the sustainable development goals outlined in *Technology for a Sustainable Future: A Framework for Action*† and embodied in the national environmental technology strategy now being developed.

Sustainable development—defined as the ability to meet the needs of the current generation without compromising the ability of future generations to meet their own needs—will require a science base that helps us to understand and measure the consequences of human activities and a technology base that provides the wherewithal for environmental stewardship and economic development. The national laboratories, with their extensive experience in solving large-scale scientific and technical problems, are well equipped to address the national and global challenges of sustainable development.

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*Office of Science and Technology Policy, *Science in the National Interest*, Executive Office of the President, August 1994.

†National Science and Technology Council, *Technology for a Sustainable Future: A Framework for Action*, Executive Office of the President, July 1994.

The activities outlined in this institutional plan show how ORNL will continue to focus its resources on advancing science in the national interest and technology for a sustainable future, in support of the new directions identified by the Department of Energy and the nation. ORNL enthusiastically accepts the challenges—and the opportunities—of living "in interesting times."

2 • Laboratory Mission, Vision, and Core Competencies

Mission

The Oak Ridge National Laboratory (ORNL) is a Department of Energy multiprogram laboratory. It is managed for the Department by Martin Marietta Energy Systems, Inc. The mission of the Laboratory is to conduct basic and applied research and development (R&D) to advance the nation's energy resources, environmental quality, scientific knowledge, educational foundations, and economic competitiveness. The Laboratory collaborates with other federal agencies, industry, and universities. It is committed to excellence in all of its activities and will be operated in full compliance with environmental, safety, and health laws and regulations.

Vision

ORNL is committed to advancing the frontiers of science and technology while addressing important national and global energy and environmental needs.

ORNL strives to be so well recognized for its excellence that students in certain fields of science and engineering regard working at the Laboratory as an essential element in their education.

In pursuit of this vision, ORNL will create new scientific knowledge, use this knowledge to solve important problems and to create new opportunities of social value, and attract the best talent from all elements of American society. Our motto is, "We bring science to life." To achieve this vision, it is imperative that we maintain our intellectual honesty and scientific integrity.

Core Competencies

A core competency is a distinguishing integration of capabilities that enables an organization to deliver mission results. Core competencies represent the collective learning of an organization and provide the capacity to perform present and future missions. They offer

comparative advantage and are difficult to reproduce. They exhibit customer focus, mission relevance, and vertical integration from research through applications. They are demonstrable by metrics such as level of investment, uniqueness of facilities and expertise, and national impact.

ORNL has identified four core competencies that satisfy these criteria. Each core competency represents an annual investment of at least $100 million and is characterized by an integration of technical foundations in physical, chemical, and materials sciences; biological, environmental, and social sciences; engineering sciences; and computational sciences and informatics. The ability to integrate broad technical foundations to develop and sustain core competencies in support of national research and development (R&D) goals is a distinguishing strength of the national laboratories. The ORNL core competencies are

- energy production and end-use technologies,
- biological and environmental sciences and technology,
- advanced materials synthesis, processing, and characterization, and
- neutron-based science and technology,

The ORNL core competencies and technical foundations are shown in a matrix format in Table 2.1. This representation shows the level of annual investment in each core competency, distributed among the four technical foundations. The total level of effort is somewhat larger than the ORNL budget because of overlap among some of the core competencies. This overlap provides synergy and additional leverage in many mission areas.

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

Table 2.1
Matrix of ORNL's core competencies
Investment[a] (in millions of dollars)

CORE COMPETENCIES	TECHNICAL FOUNDATIONS			
	Physical, Chemical, and Materials Sciences	Biological, Environmental, and Social Sciences	Engineering Sciences	Computational Sciences and Informatics
Energy Production and End-Use Technologies	104	12	44	9
Biological and Environmental Sciences and Technology	23	88	37	12
Advanced Materials Synthesis, Characterization, and Processing	95	—	36	6
Neutron-Based Science and Technology	63	1	48	6

[a]FY 1993 operating expenses to the nearest $1 million.

3 • Laboratory Strategic Plan

3.1 • Situation Analysis

3.1.1 • Assumptions

- ORNL will remain a DOE-owned national laboratory.
- ORNL's most important role will continue to be support for DOE missions.
- ORNL's scientific and technical capabilities will be applied to a range of national needs corresponding to DOE's mission.
- The current national debate will confirm DOE's assumption of a role in five major mission areas:
  - science and technology
  - energy resources
  - environmental quality
  - industrial competitiveness
  - national security
- Industrial competitiveness will become increasingly important, while emphasis on national security will decline.
- Continuing constraints on federal funding for research and development (R&D) will be coupled with demands for cost-effective operation, relevance to national needs, and accountability.

3.1.2 • Strengths, Concerns, and Opportunities

- Strengths
  - Experienced and talented staff
  - Broad range of research tools and facilities
  - Capability for integrated, multidisciplinary R&D
  - Record of accomplishment in working with the private sector
- Concerns
  - Need for cost-effective operation and improved resource management
  - Aging infrastructure
  - Legacy issues
  - Continuing pressure on federal funding
  - Administrative barriers to collaboration
- Opportunities
  - Revolutionary changes are anticipated in the fields of science and technology in which ORNL is involved.

- The role of the federal government in R&D is shifting.
- We have the opportunity to explore new research areas, improve the way we do business, and expand our customer base.

3.1.3 • Strategic Planning: New Focus for DOE

- DOE's planning is structured around five business areas, which do not parallel the existing organizational or budget arrangement.
- ORNL is using DOE's new structure as a model for conducting its strategic planning.
  - The *ORNL R&D Strategic Plan* has been revised to correspond to the format of the DOE Strategic Plan.
  - The revised plan has been distributed to ORNL staff members, and stakeholder input is being collected and incorporated.
- Mapping of the existing programs and budgets onto this new model is not always straightforward.

3.2 • Mission Areas, Goals, and Strategies

ORNL has identified six mission areas:

- science and technology,
- energy resources,
- environmental quality,
- industrial competitiveness,
- national security, and
- business practices.

The first five mission areas correspond to the five business areas of the DOE Strategic Plan. The sixth area addresses the critical success factors identified by DOE; this area has been identified as a mission area to indicate ORNL's commitment to excellence in all aspects of its mission.

For each mission area, ORNL has established a top-level "vision" that is supported by a set of goals. Strategies and success indicators for achieving these goals have been identified. Action plans will be prepared to implement these strategies. Goals, strategies, and success indicators are listed here by mission area.

3.2.1 • Science and Technology

Vision: Apply and enhance scientific and technical capabilities to address national needs.

Goal 1. Develop and enhance core competencies and technical foundations that are appropriate to and support the Laboratory's current and future missions, and use them to address national needs.

Strategies

- Pursue initiatives that exploit existing technical strengths and the development of new capabilities to enhance and expand the application of ORNL's core and institutional competencies.
- Enhance high-performance computing and informatics and advanced instrumentation programs to strengthen emerging core competencies.
- Strengthen the integration of basic and applied programs to address solutions to national problems.

Success Indicators

- Funding levels of programs supporting core competencies
- Improved linkages between basic and applied programs
- Number of partnerships with academia and industry
- Number of related technology options created and/or transferred to industry

Goal 2. Generate new knowledge and insight that support current and future Laboratory and DOE missions by maintaining strong fundamental and basic research programs.

Strategies

- Strengthen the excellence of the fundamental and basic science programs.
- Strengthen external interactions and partnerships in fundamental and basic research, with an emphasis on universities in the southeastern United States.
- Use multidisciplinary teams of researchers to address major initiatives of national importance.
- Provide a stimulating research environment that creates a climate in which breakthroughs occur.

Success Indicators

- Scientific excellence, as judged by peer review, advisory committees, awards, publications, and citations
- Funding levels of fundamental and basic research programs
- Impact of research on science and technology
- Number of partnering research programs aimed at solving fundamental and basic problems related to DOE's missions
- Staff and user evaluation of research environment

Goal 3. Design, construct, and operate world-class research facilities.

Strategies

- Operate all facilities to promote leading-edge individual and multidisciplinary scientific and technical advances in a safe and cost-effective manner.
- Maintain and upgrade facilities to maximize their usefulness.
- Ease access for users and increase their involvement in facility evaluation.

- Establish new facilities to address national needs and to facilitate partnerships with industry, universities, and other government institutions.

Success Indicators

- Improved facility performance and increased user participation
- Impact of operating facilities, as judged by the scientific output, user evaluations, and advisory committee reports
- Cost-effective operation and construction coupled with improved environmental, safety, and health (ES&H) performance
- Designation of unique ORNL facilities as national user facilities

Goal 4. Construct and operate the Advanced Neutron Source (ANS) to provide an unparalleled facility for neutron science and technology that will enhance the nation's industrial competitiveness and the health of its citizens.

Strategies

- Sustain broad support in the scientific community and industry through active user groups and development of new initiatives.
- Strengthen regional support by promoting partnerships with the University of Tennessee, the Tennessee Valley Authority, and state agencies.
- Emphasize risk-based, cost-benefit analysis to help set priorities and make decisions.

Success Indicators

- Funding for ANS
- Achievement of construction cost and schedule milestones and favorable project reviews
- Continued support from state of Tennessee for a user facility and from industry for the ANS programs and facilities
- Range of applications of ANS-produced neutrons
- Number of guest users

Goal 5. Construct and operate the Center for Biological Sciences (CBS) and the Advanced Materials Science and Engineering Complex (AMSEC) to enhance integrated research and partnership activities and to extend DOE leadership in biological and materials sciences.

Strategies

- Develop broad support through public education, active user groups, and endorsements from the scientific community, including the University of Tennessee and other regional universities.
- Work with industry to provide guidance and to form partnerships based on opportunities provided by the new facilities.

Success Indicators

- External support for biological and materials programs with increased integration of basic and applied sciences
- Construction funding and achievement of cost and milestone schedules
- Number of guest users
- Number of industrial partnerships

Goal 6. Focus ORNL's education and training programs on improving scientific literacy in the southeastern United States and on building a diverse and technically competent work force for the nation.

Strategies

- Expand ORNL's effort to increase scientific and technical literacy through precollege education and information transfer, with a special emphasis on providing innovative information technology to students and teachers.
- Enhance partnerships with other organizations (e.g., the Appalachian Regional Commission); schools, colleges, and universities in the state and region, especially historically black colleges and universities; and the private sector.
- Strengthen existing collaborative education programs with regional colleges and universities (e.g., Oak Ridge Graduate School of Biomedical Sciences) and establish new programs (e.g., in radiochemistry).
- Use internal and external education programs to improve the staff's scientific and technical capabilities and diversity and to provide a more challenging and stimulating research environment.

Success Indicators

- Number of partnerships with educational institutions and the private sector
- Number of student and teacher programs and participants
- Funding for education programs
- Excellence and diversity of the staff
- Impact of ORNL programs, measured by comparing science and math test scores of students participating in ORNL programs and the percentage of those participants entering science and engineering disciplines to the same information for students in the same schools prior to program participation over five- and ten-year periods

3.2.2 • Energy Resources

Vision: Conceive, develop, and demonstrate safe, economical, reliable, and environmentally sustainable technologies for efficient energy supply and use.

Goal 1. Develop affordable technologies to contribute to the DOE goal of improving overall building efficiency by 50%.

Strategies

- Target the factory manufactured housing industry for collaboration.
- Build on existing heat pump expertise.
- Develop partnerships with stakeholders who can implement efficiency.
- Develop programs that couple energy efficiency with other benefits.

Success Indicators

- Substantial funding for manufactured housing research in 1995
- Commercialization of an advanced insulation (> R-20/in.) by 1996
- Major role for ORNL in implementing the Climate Change Action Plan
- Introduction of one or more heat-actuated heat pump developments into the market in 1997

Goal 2. Demonstrate sustainable biomass energy systems that can meet a substantial portion of the energy needs of the United States and other parts of the world.

Strategies

- Use the existing feedstock program as a base to expand the ORNL biomass effort.
- Aggressively pursue collaborative opportunities with U.S. Department of Agriculture, the Tennessee Valley Authority, private industry, and international organizations to become involved in specific biomass energy projects.

Success Indicators

- Number of research, development, and demonstration (RD&D) collaborations in place with U.S. industry, other DOE laboratories, universities, producers, and the U.S. Department of Agriculture in international biomass energy activities and projects, with emphasis on the areas of dedicated feedstock production systems, environmental monitoring, bioprocessing, biotechnology, and conversion technologies
- Establishment of an integrated biomass energy scale-up or demonstration project with a liquid-fuels or energy producer (e.g., the Tennessee Valley Authority) using technical capabilities developed at ORNL, by 1998
- Number of sponsors for biomass-related technology development, analysis, and assessments of biomass potential and effects and for biomass energy education efforts
- Demonstration of the technical ability to produce 2 EJ of fuel from biomass waste and energy crops

Goal 3. Assist the utility industry in providing an efficient energy delivery and use system.

Strategies

- Focus on electrical transmission and distribution issues.
- Broaden the scope of the ORNL Integrated Resource Planning program by working with the Tennessee Valley Authority or other utilities to emphasize customer requirements.
- Develop an expanded superconducting technology program with other laboratories, focusing on electric power equipment (transformer, transmission line, generator, and motor).
- Provide effective field management of the DOE program on electromagnetic field effects.

Success Indicators

- Number of ORNL-developed techniques adopted by the utility distribution system
- Development and publication of standard protocols for measurement of electric and magnetic fields
- Establishment of an industry-led, multilaboratory partnership to construct and demonstrate a high-temperature superconductor generator

Goal 4. Respond to changing national policies on fission energy and nuclear materials while maintaining a record of achievement and excellence in nuclear technology and safety R&D.

Strategies

- Develop new programs that address reactor safety issues in the former Soviet Union states.
- Broaden the scope and roles of ORNL in the DOE Radioisotope Thermoelectric Generator Program to support future NASA missions.
- Serve as a Nuclear Regulatory Commission (NRC) lead laboratory in materials, instrumentation and controls, severe accident analysis, and analysis and evaluation of operational data.

Success Indicators

- Establishment of new programs with several agencies to address important nuclear safety issues in former Soviet Union states
- Selection of ORNL by DOE for new roles in the Radioisotope Thermoelectric Generator Program
- Maintenance of or increase in the Martin Marietta Energy Systems market share of support that DOE laboratories provide to the NRC

Goal 5. Be selected as the primary location for the nuclear technology phase of the U.S. fusion energy program.

Strategies

- Continue extensive national and international collaborations, focusing on the International Thermonuclear Experimental Reactor (ITER) and the Tokamak Physics Experiment.
- Continue extensive national and international collaborations.
- Lead the international conceptual design activity for a Fusion Materials Irradiation Facility.
- Obtain support for a U.S. Spherical Tokamak Experiment as a forerunner of the Volume Neutron Source.
- Develop a proposal for an ITER site, which could also attract the national fusion nuclear site if ITER is built abroad.

Success Indicators

- ITER site proposal developed to meet DOE schedule
- Designation of ORNL as DOE's lead lab for materials development
- DOE continuation of a long-range, broad-based ORNL program
- Significant DOE funding for the Spherical Tokamak program
- Continuing collaborations as a major part of the ORNL program

Goal 6. Improve the efficiency of clean conversion of fossil fuels.

Strategies

- Concentrate on areas related to ORNL materials expertise (e.g., super-efficient turbines, hot-gas cleaning, high-temperature gas separations).
- Develop a base of support in the DOE Office of Fossil Energy, Congress, and industry that will assure important and significantly funded roles for ORNL in the reorganized DOE Office of Fossil Energy.

- Develop a plan of research leading to technologies that will minimize emissions of CO_2 and provide for its removal and disposal.
- Promote ORNL/industry developments through cooperative test projects.
- Initiate study of new approaches to the production of hydrogen.

Success Indicators

- ORNL maintenance of management responsibility for DOE's Fossil Energy Materials Program, with increased funding for materials and bioprocessing
- Completion and publication of tests of hot-gas cleaning components
- Issuance of a plan for CO_2 minimization, removal, and storage R&D
- Development of new materials and devices for gas turbines and gas separation
- Funding for novel hydrogen production techniques

3.2.3 • Environmental Quality

Vision: **Provide the knowledge and technology needed to sustain, protect, and restore the environment and to support practices and policies that promote sustainable development.**

Goal 1. Quantify the dynamics of environmental systems by developing and applying a comprehensive understanding of biological, chemical, physical, and behavioral systems.

Strategies

- Develop and use advanced computational systems for managing, analyzing, and visualizing large amounts of complex environmental data.
- Measure anthropogenically introduced materials and use analytical and computational capabilities to model their movement and effects in complex environmental systems.
- Quantify the behavior of forest ecosystems and develop theories for extrapolation to varied environments of the eastern United States.
- Use the expertise in instrumentation, micromanufacturing, and robotics to develop instrumentation for characterizing ecosystems.

Success Indicators

- Development and use of modeling tools to predict the processes governing ecosystem dynamics
- Establishment of an integrated ORNL program to study the microbial and plant genomes and their ecology
- Level of support for major environmental data centers, measured in terms of capabilities for storing and retrieving terabytes of data
- Establishment and use of experimental field sites with advanced instrumentation for global change simulation studies

Goal 2. Develop and demonstrate effective diagnostic, environmental remediation, and waste management technologies to meet DOE and other national and international needs.

Strategies

- Develop risk analysis methodologies to evaluate and prioritize the social, economic, ecological, and health impacts of remediation alternatives.
- Use the Center for Environmental Technology to strengthen the linkages between risk assessment, R&D, and technology transfer and deployment.
- Within ORNL, strengthen the degree of coupling between basic and applied research organizations.

Success Indicators

- Number of ORNL-developed technologies for environmental remediation and waste management in the field
- Cost savings and stakeholder acceptance associated with these technologies
- Number of ORNL-derived automated risk assessment systems and risk characterization procedures in use in the field
- Extent of national roles in focus areas for environmental restoration and waste management

Goal 3. Design and implement effective environmental protection systems, including effluent control, waste minimization, and environmental monitoring and compliance, for the Oak Ridge reservation.

Strategies

- Identify major risk-related environmental restoration problems on the Oak Ridge reservation and establish a decision analytic framework for cost-effective remediation of these problems.
- Increase emphasis on ORNL In-House Energy Management Program.
- Apply R&D advances to improve environmental monitoring and compliance programs at DOE's Oak Ridge facilities.

Success Indicators

- Number of ORNL-developed technologies for environmental, safety, and health applications deployed in the field
- Energy cost and waste generation statistics for ORNL
- Improved environmental, safety, and health compliance, measured via cost reductions and performance evaluations

Goal 4. Develop and deploy techniques for supporting socially and environmentally responsible technology deployment and use, economic development, and public policy.

Strategies

- Develop and demonstrate techniques for assessing the social and environmental acceptability of new technologies and options for sustainable development.
- Develop international private sector–government partnerships to address global issues in both industrial and emerging nations.
- Develop innovative metrics for the environmental factors most responsible for quality of life and worker productivity.

- Integrate research in transportation, building energy efficiency, energy production and use, and manufacturing to support the development of sustainable and more livable cities.

Success Indicators

- Acceptance of ORNL-developed techniques for assessment of current or emerging energy technologies
- Number and extent of partnerships for industrial development in which renewable resources and biodiversity play a major role
- Application of ORNL-developed solutions to urban development and renewal

3.2.4 • Industrial Competitiveness

Vision: Add value to the economy by working collaboratively with U.S. industry to assist in developing the technological innovations that result in high-wage jobs.

Goal 1. Apply ORNL capabilities to enhancing industrial competitiveness by

- building integrated R&D alliances with the public and private sectors,
- using cooperative R&D agreements (CRADAs) and other mechanisms to develop and transfer technologies and processes,
- maximizing opportunities for customers to use ORNL's unique facilities and centers of excellence, and
- emphasizing developments that reduce environmental impacts

Strategies

Biotechnology

- Develop new opportunities through the Center for Biotechnology, the Oak Ridge Center for Healthcare Industry Development, the Center for Environmental Technology, and other partners

Resource Efficiency and Pollution Prevention

- Demonstrate processes and techniques on the Oak Ridge reservation
- Build ORNL roles in national initiatives for resource efficiency and pollution prevention (e.g., Advanced Turbines, Pulp and Paper, Industrial Motors, and Clean Industry).

Transportation

- Focus on application of ORNL capabilities in materials and computing to transportation R&D for a broad customer base, with emphasis on the Oak Ridge Transportation Technology Center (ORTRAN) and the Tennessee Transportation Technology Coalition.

Manufacturing Technologies

- Integrate ORNL capabilities into the Oak Ridge Centers for Manufacturing Technology
- Expand ORNL's role in the Regional Assistance Program.

Advanced Materials

- Increase integration of basic and applied research programs to improve evaluation and exploitation of discoveries
- Increase emphasis on scale-up, database development, and transfer to industry

Simulation, Modeling, and Computational Engineering

- Collaborate with industry and other national laboratories through the Computational Center for Industrial Innovation to support the National Information Infrastructure
- Address Grand Challenges through collaborative projects

Success Indicators

- Number of partnerships with industry, other national laboratories, other federal agencies, and the private sector
- Number of ORNL-developed technologies, processes, and techniques transferred to industry
- Number of industries requesting and receiving assistance
- Commercialization of ORNL-developed materials

Goal 2. Establish ORNL as a cost-effective, responsive, and reliable partner in promoting industrial competitiveness.

Strategies

- Remove barriers to collaboration by improving systems for protecting intellectual property; by streamlining procedures for Work for Others, CRADAs, industrial assignments, and other collaborative arrangements; and by improving industry awareness of and access to ORNL capabilities
- Use personnel exchanges and industry presence on division, program, and user center advisory boards to enhance ORNL researchers' understanding of industrial issues
- Improve industry awareness of and access to the capabilities of ORNL and the Oak Ridge complex

Success Indicators

- Industry awareness of ORNL capabilities (as indicated by queries from potential partners and/or survey results)
- Industry selection of ORNL as "partner of choice"
- Number of CRADAs and other collaborative arrangements
- Number of users of designated user facilities
- User and customer satisfaction, indicated by survey results and "repeat business"

3.2.5 • National Security

Vision: Contribute to maintaining the technology infrastructure and core competencies needed to ensure national security while assisting industrial competitiveness

Goal 1. Maintain technology and competencies that are responsive to national security needs.

Strategies

- Expand nuclear fuel cycle RD&D and analytical capabilities for dealing with proliferation issues.

- Maintain capabilities for recovery and purification of transuranium element isotopes and for characterization of their physicochemical properties.
- Develop innovative approaches and establish ORNL roles in the disposition of weapons-usable fissile materials.

Success Indicators

- Continuing subset of staff members involved with national security programs
- Continued production of heavy elements

3.2.6 • Business Practices

Vision: **Operate ORNL in a manner that supports our mission, meets the expectations of our customers, expedites the performance of research programs, and is rewarding to our staff.**

Goal 1. Conduct all operations in a safe and environmentally responsible manner.

Strategies

- Enlist, empower, and support all personnel in the challenge of protecting public and occupational health and the environment; conserving natural resources; preventing pollution; and complying with laws, regulations, orders, and agreements.
- Focus on hazard elimination, waste minimization, and pollution prevention in all processes and activities.
- Use risk-based analysis to prioritize environment, safety, and health (ES&H) challenges.

Success Indicators

- ES&H performance as indicated by DOE-wide performance indicators
- Staff awareness of and satisfaction with ES&H-related operational practices, as measured by employee communications surveys

Goal 2. Reduce the cost of doing business by 20% within five years.

Strategies

- Identify and implement more cost-effective methods of operation.
- Continue and strengthen Columbus Initiatives program to identify and implement cost-savings ideas.
- Improve teaming between research and support staffs to ensure that maximum benefits are derived from sponsors' funding.

Success Indicators

- Reduction in divisions' burden, materials, and services cost by 10% over the next five years
- Reduction in ORNL-driven laboratory overhead rates (Pools A, B, and C) by 10% over the next five years
- Cost savings/avoidances reported via Columbus Initiatives program

Goal 3. Revitalize the Laboratory infrastructure.

Strategies

- Build internal and external consensus on infrastructure needs.

- Improve condition of existing structures.
- Develop and deploy effective systems for management and use of general-purpose equipment (GPE) and programmatic capital equipment funding.
- Strengthen the site planning process and use it to improve integration and coordination of general-purpose and programmatic initiatives.

Success Indicators

- Condition of infrastructure, measured by Condition Assessment Surveys
- Increased capital funding levels
- Cost of new construction, benchmarked against cost at other national laboratories

Goal 4. Attract and retain the staff needed to achieve programmatic goals.

Strategies

- Develop and sustain systems for fostering employee development and productivity.
- Provide safe, comfortable, and accessible work environments for all employees.
- Build and maintain a culturally diverse work force.
- Improve the user friendliness of support systems.

Success Indicators

- Statistics on staff recruitment and retention
- Employee awareness of and satisfaction with development opportunities, work environments, and workplace inclusivity, as measured by employee communications surveys
- Perceived ease in "getting things done," as measured by employee communications surveys

Goal 5. Improve ORNL responsiveness to internal and external stakeholders.

Strategies

- Encourage employee empowerment.
- Include effective communication with employees as a measure of performance for managers.
- Measure customer focus and satisfaction, and strive for continuous improvement.
- Address public perceptions of ORNL through activities that involve the public, through information products, and through development of public-use areas.

Success Indicators

- Employee perceptions of responsiveness, measured via employee communications surveys and evaluations of supervisors
- Customer satisfaction, measured via Performance Measurement Team (PMT) process and customer surveys
- Public perceptions, measured via media coverage, information requests, visits, and tours
- Quality management and achievement, measured using criteria for Malcolm Baldrige National Quality Award

4 • Major Laboratory Initiatives

4.1 • Advanced Neutron Source

The Advanced Neutron Source (ANS) will provide the most intense, steady-state source of neutrons in the world, along with state-of-the-art guide halls and experimental facilities. It will be used to develop new materials; to produce specialty isotopes for medical, military, and industrial applications; to explore fundamental questions in materials science and engineering, physics, chemistry, biology, and nuclear science; to irradiate and test materials for new energy options; to produce positron beams for surface and defect studies; and to serve over 1000 users per year from universities, industry, and other government laboratories.

A portion of the mission needs of the ANS is currently provided by the High Flux Isotope Reactor (HFIR) at ORNL and the High Flux Beam Reactor (HFBR) at Brookhaven National Laboratory; however, both of these research reactors are approaching 30 years of age, are currently operating at reduced capacity because of aging components, and cannot be modified to effectively meet future neutron research needs. The ANS will replace both of these facilities and provide greatly increased capabilities. The technical specifications for the ANS are shown in Table 4.1.

The relative availability of neutrons that will be provided by the ANS for experiments at various energies (neutron types) is compared in Table 4.2 to the neutron fluxes available from today's research reactors, including the Institut Laue-Langevin (ILL) reactor in France. Most fundamental breakthroughs in applications of neutron sources during the past 40 years have been directly linked to increases in available neutron flux. The neutron flux at ANS will be the highest in the world, five to ten times that of the ILL reactor, today's premier research reactor. The ANS also has a greater capacity for materials study. These capabilities will make the ANS the world's foremost center for neutron research.

The Conceptual Design Report for the ANS was issued in June 1992, and a review with recommendations to proceed was completed by DOE in December 1992. The justification and need for ANS have been repeatedly confirmed by the scientific and technical community through six major studies since 1977. The most recent, by the DOE Basic Energy Sciences Advisory Committee Panel on Neutron Sources for America's Future in January 1993, listed completion of the design and construction of the ANS as the panel's number one priority. The ANS was in the President's FY 1995 budget as a construction line item. Although the construction status did not survive House and Senate actions, the ANS was funded at $21 million in the final FY 1995 budget with favorable language that allows the project to engage industry in the final design process. A model of the reactor, the guide halls, the support buildings, and the experimental facilities of the ANS is shown in Fig. 4.1.

Table 4.1
Technical specifications for the ANS

Scientific and production capabilities	
Maximum thermal neutron flux, $m^{-2} \cdot s^{-1}$	7.5×10^{19}
Number of neutron beams	
Hot	2
Thermal	9
Cold	16
Very cold	2
Number of neutron scattering stations	48
Number of irradiation facilities	
Transuranium isotope production	30
Other isotopes	8
Materials testing	11
Number of materials analysis facilities	10
Gamma irradiation facilities	1
Positron production facilities	1
Reactor characteristics	
Type	Heavy water cooled and reflected
Fission power, MW	330
^{235}U loading, kg	17
Fuel form	U_3Si_2
Fuel plates	Annular involute plates, aluminum clad
Coolant temperature, °C	45 (inlet), 85 (outlet)
Coolant pressure, MPa	3.2 (inlet), 1.7 (outlet)

Table 4.2
Neutron type flux comparison

	Total flux of different neutron types			
Neutron type	HFBR	HFIR	ILL	ANS
Hot	0	0	470	470
Thermal	350	410	1,600	11,500
Cold	30	0	700	16,000
Very cold	0	0	35	250
Ultracold	0	0	460	2,800

Budget projections for the planning period are given in Table 4.3. The ANS is supported through the DOE Office of Basic Energy Sciences and is managed by the DOE Office of Nuclear Energy.

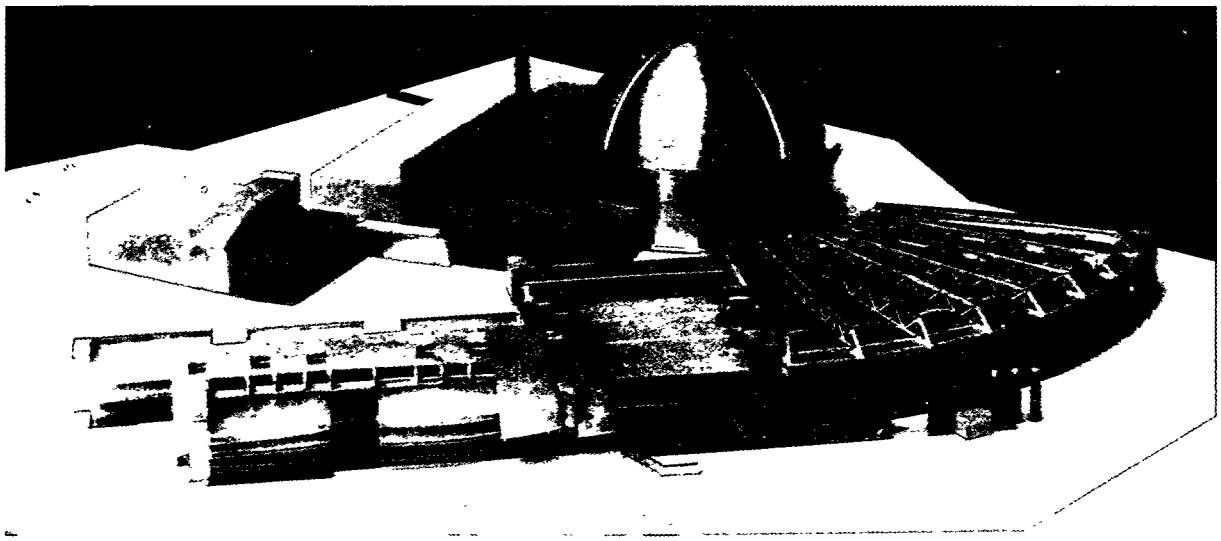


Figure 4.1
Model of the ANS reactor, guide halls, support buildings, and experimental facilities.

Table 4.3
Budget projections for the planning period by fiscal year for the Advanced Neutron Source
($ in millions—BA)[a]

	1995	1996	1997	1998	1999	2000
Operating expense	20.0	47.3	49.1	50.1	39.4	55.6
Capital equipment	1.0	4.6	5.4	6.0	3.8	2.0
Construction line item	0.0	98.3	203.5	365.3	522.7	524.1
Total	21.0	150.2	258.0	421.4	565.9	581.7

[a]Actual dollars.

The Institute for Neutron Sciences (INS) will be a joint venture of ORNL, the University of Tennessee (UT), and regional universities to exploit the ANS and the attendant benefits of neutron-based research within the area. Financial support for conceptual design of the INS is being provided by the state of Tennessee through UT. The INS will support the ongoing research and graduate education programs of UT and other regional universities by providing a site at ORNL for students and faculty to conduct joint research at the ANS, by increasing access to ORNL user facilities and staff, by holding workshops, and by otherwise promoting enhanced interaction among university, industry, and national laboratory researchers. The INS will consist of offices for collaborating regional scientists and guests, as well as conference and teleconference facilities to provide scientific interchange through broadcasts of seminars, lecture series, workshops, and other significant technical presentations and discussions. The INS will be constructed adjacent to ORNL at an approximate cost of $10 million.

4.2 • Center for Biological Sciences

The Center for Biological Sciences (CBS) is proposed to provide a facility that will integrate and enhance the future research goals of programs in the biological sciences at ORNL. The core of the new facility, located at the west end of the X-10 site, will be the Laboratory's Biology Division, currently housed at the Oak Ridge Y-12 Plant. More than just a new building for the Biology Division, as badly needed as that is, the CBS will bring staff scientists and students in the UT–Oak Ridge Graduate School of Biomedical Sciences into close contact with their colleagues in related research divisions. These interactions will substantially enhance both ongoing and emerging programs in protein engineering, computational and structural biology, genome research, mammalian mutagenesis, medical and environmental biotechnology, and other fields. A major factor in the enhancement will be the increased attractiveness of the facilities to industry for cooperative research and to Southeastern universities for collaborative exchanges.

The present Biology Division facilities at Y-12 are nearly 50 years old and are obsolete. Because of their condition, they impede both ongoing and proposed research. Studies show that retrofitting these buildings to meet present needs would cost at least as much as a new building; preliminary estimates also project significant savings in operating cost resulting from moving out of the present facilities. The 13-km (8-mile) separation of current Biology Division facilities from the main ORNL site hampers collaborative efforts on key initiatives such as biotechnology (interaction with the existing ORNL Bioprocessing Research Facility), structural biology (interaction with the proposed ANS), and computational biosciences (interaction with the Center for Computational Sciences). The CBS will correct these deficiencies and will strengthen ORNL's contributions to these and other initiatives.

The proposed CBS will be a two-story structure of steel frame and masonry construction, as shown in Fig. 4.2. The facility's size is ≈23,225 m^2 (250,000 ft^2). It will be designed with a central core to house division-wide research support and administrative functions and three interconnecting wings for the division's laboratory and animal facilities. The building will be zoned by functions and arranged to provide high-efficiency operations. The functional areas include conventional and barrier-isolated animal facilities for housing and caring for a diversity of mouse genetic strains (e.g., animal rooms, cage and bottle-washing stations, and feed and bedding storage); biochemical research space for conducting mammalian genetics, cancer biology, molecular genetics, structural biology, and protein engineering (e.g., laboratories, equipment space, and office space for scientists, technicians, guests, and students); the UT–Oak Ridge Graduate School of Biomedical Sciences; and administrative operations such as a library, a computer center, a cafeteria, and division administration.

Special facilities required by the ORNL Biology Division and related programs will be integrated into the building in an efficient and cost-effective manner. These facilities include areas suitable for gamma and X-ray irradiation, barrier areas for working with specific pathogen-free animals or hazardous materials, darkrooms, electron microscopy facilities, environmentally controlled rooms, fermenters for growing large quantities of cells, a crystallography laboratory, tissue culture areas, and glassware kitchens. All systems will be designed and installed to provide an energy-efficient environment that is suitable for animals, research, and personnel.

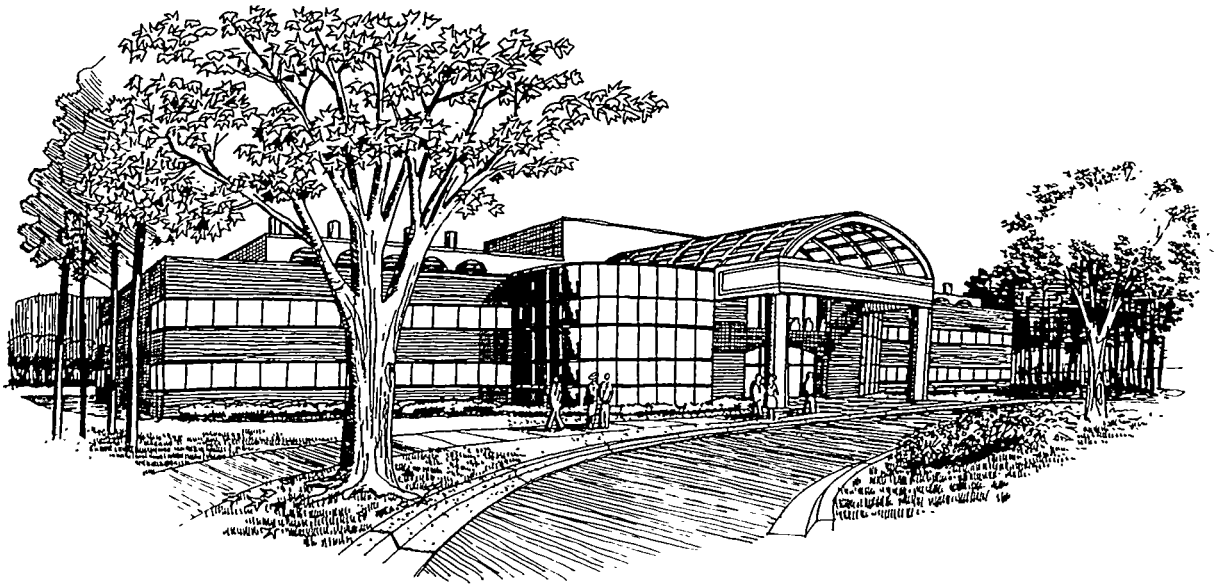


Figure 4.2
Conceptual drawing of the proposed Center for Biological Sciences.

Funding for construction of the CBS is being pursued through the Office of Health and Environmental Research (OHER) in DOE's Office of Energy Research for FY 1996. The total estimated cost of the facility is $102.9 million, and the total project cost (including pre–FY 1995 funding of $0.7 million) is about $106.7 million (see Table 4.4). FY 1992 funds were provided for pre-Title I activities and other planning tasks for the CBS. Preparation of National Environmental Policy Act (NEPA) documentation has begun, the Security Plan has been prepared, site geotechnical evaluation is nearing completion, and the Safety Assessment has been completed.

A revised project data sheet (1B7 Form) was submitted to the Office of Energy Research in April 1994. A field work proposal (FWP) has been submitted to OHER for operating funds supporting the CBS as a major construction line item and for preparing the necessary supporting data. The CBS budget validation review has been held each year since 1991; the most recent review was in Oak Ridge, Tennessee, in May 1994.

Table 4.4
Budget projections for the planning period by fiscal year for the Center for Biological Sciences
($ in millions—BA)

	1995	1996	1997	1998	1999	2000
Operating	0.1	0.1	0.1	0.1	2.7	0
Construction line item	0.0	18.0	43.0	41.9	0	0
Total	0.1	18.1	43.1	42.0	2.7	0

4.3 • Advanced Materials Science and Engineering Complex

A 1989 study by the National Research Council demonstrates that materials science and engineering (MS&E) is one of the most rapidly developing areas of science—one that is vital to the future competitiveness of the United States in the international marketplace.* Cutting-edge research and close cooperation among universities, industries, and national laboratories are needed to carry ideas rapidly from inception to the marketplace. A national plan drafted by the Office of Science and Technology Policy (OSTP) as a follow-on to the National Research Council study forms the basis for increased emphasis on materials research and development (R&D) at a national level.

Among DOE's national laboratories, ORNL has one of the strongest materials programs. Indeed, the ORNL programs in high-temperature metals and alloys, ceramics, composites, and superconductors are unparalleled successes. ORNL has established programs in synthesis and processing science that span a wide range of materials systems. ORNL is also a leader in user programs and technology transfer through cooperative R&D agreements (CRADAs) and licensing. These activities have grown rapidly and will increase even faster because of recent legislation removing barriers to technology transfer.

Universities and colleges in the southeastern United States have numerous innovative materials R&D programs that collectively span a broad range of disciplines, from materials chemistry to materials physics to materials engineering and testing. During the last few years, the Southeastern Universities Research Association (SURA) and the Oak Ridge Institute for Science and Education (ORISE) have explored ways to simplify and encourage joint materials research activities with ORNL. This approach not only benefits large, established programs but also enhances small programs at individual universities through synergistic interactions. In addition, the University of Tennessee at Knoxville (UTK) and ORNL have a close working relationship. Faculty and graduate students from UTK participate in collaborative research at ORNL, and ORNL staff members serve as adjunct professors and thesis advisors at UTK.

To make the ORNL materials facilities and those of the industries and universities in the region available for joint cooperative projects, ORNL proposes the Advanced MS&E Complex (AMSEC), which will be structured to coordinate with the OSTP plan. By consolidating a number of existing programs and providing new buildings and facilities, the AMSEC will enhance collaborative interactions in MS&E. The plan of the complex addresses identified national, regional, and local needs for materials R&D, and it will support ORNL's rapidly expanding user programs and technology transfer activities.

The AMSEC also meets a critical need to alleviate poor conditions in materials facilities at ORNL. The need to replace substandard laboratories in the Solid State Division has been recognized for decades, and during this time the condition of these facilities has deteriorated. The added space will also alleviate severely overcrowded conditions in the Metals and Ceramics Division.

To ensure marketplace success, industry must guide and participate in the R&D and manufacturing science activities. Active participation of industry will be fostered by the

*National Research Council, *Materials Science and Engineering for the 1990s: Maintaining Competitiveness in the Age of Materials*, National Academy Press, Washington, D.C., 1989.

AMSEC, which will make available ORNL's wide-ranging multidisciplinary skills; capabilities in fabrication, characterization, and testing; independent and objective outlook; and ability to work with and protect proprietary information.

The AMSEC will be constructed in the late 1990s to the east of the main X-10 site. The centerpiece of the complex will be the Materials Research and Development Laboratory. This building will provide modern facilities for the sophisticated, state-of-the-art equipment for materials characterization, synthesis, and processing that is essential for advanced materials R&D. The Materials Research and Development Laboratory will serve as a focus for the integrated materials science research community, providing access to a specialized, and unique, collection of R&D equipment to users from industry, academia, and other national laboratories. In addition, the facility will serve to centralize the materials science and engineering activities that are currently located in more than 15 buildings spread over the ORNL site.

The Materials Research and Development Laboratory will have approximately 18,600 m^2 (200,000 ft^2) and will provide over 50 laboratories and 150 offices for staff and users. The building will replace aging facilities that cannot be upgraded to provide the vibration-free, isolated laboratories that are required to attain the specified technical performance of much of today's microanalysis equipment. As this equipment has become more sensitive, its performance is limited not by the instruments themselves but by the environment in which they are sited. Electromagnetic fields, building vibrations, and even low acoustic noise cause degradation of performance. Building services and traffic patterns will be routed to enhance the isolation of sensitive instruments. The facility will also emphasize information management and allow the acquisition, analysis, and routing of digital images, within ORNL and to external users.

Beyond the specialized needs of characterization equipment, the Materials Research and Development Laboratory would also provide facilities that are designed specifically to accommodate modern synthesis and processing research and to meet the environmental, safety, and health requirements of ORNL's MS&E research programs. The building would provide for unequaled integration of ORNL's R&D programs in synthesis, processing, fabrication, characterization, and modeling. Integrated facilities such as this, containing a concentration of state-of-the-art equipment and available to a broad spectrum of outside users, will be essential to future research as materials R&D issues become more complex and the necessary equipment becomes more complicated and expensive. The overall goal is to provide an environment that fosters the development of the understanding of materials and materials-related processes and phenomena, from the atomic structure to the macroscopic properties, that is necessary to underpin energy technologies and industrial endeavors—and to ensure the nation's continued economic competitiveness in these crucial areas.

The total cost of construction for the Materials Research and Development Laboratory will not exceed $95 million. Additional cost for the initial capital equipment is estimated at $12 million. Design will begin in FY 1997 with construction completed in FY 2000. The possibility of constructing the facility in stages will be considered and incorporated in the initial design. Budget projections are shown in Table 4.5.

Table 4.5
Budget projections by fiscal year for the Materials Research and Development Laboratory
($ in millions)

	1996	1997	1998	1999	2000
Capital equipment	0	0	3	4	5
Line-item construction	0	3	20	40	32

The Institute for the Study of Advanced Materials (ISAM) is an initiative of the university community of the Southeast, led by SURA. It responds to a need for the establishment of a campus-like presence in the Southeast to maximize the interaction between academic, industrial, and ORNL scientists and engineers who work in the materials area and to optimize the process for transferring technology from research to industrial utilization. ISAM is intended to integrate and enhance the entire spectrum of MS&E opportunities at ORNL and to make them accessible to universities and industries in the Southeast. ISAM initiatives will reflect the talents, facilities, and capabilities residing in the Southeast and will address nationally significant problems that transcend the capabilities of the individual institutions.

ISAM will support ongoing research and graduate education programs of the Southeastern universities and will provide industry-oriented training opportunities for practicing scientists and engineers. It will serve as a gateway to ORNL, with office and conference facilities for participating researchers, meeting and training facilities, and a modern communications network. The SURA communications network, SURAnet, will be tied into ISAM to provide scientific interchange. Education programs will take advantage of SURA faculty as well as ORNL research facilities.

ISAM will be operated through the cooperation of SURA, ORISE, and ORNL. Financial support for the Institute is envisioned as joint funding from DOE's Office of Basic Energy Sciences, the National Science Foundation's Division of Materials Research, state funds from participating universities, and industrial partnerships. Establishment of ISAM will involve construction of a building next to ORNL at an approximate cost of $18 million. Budget projections are given in Table 4.6.

Table 4.6
Budget projections by fiscal year for the Institute for the Study of Advanced Materials
($ in millions)

	1996	1997	1998	1999	2000
Capital equipment	0	0	0	0.7	0.8
Line-item construction	0	0	2.0	8.0	8.0

4.4 • Other Initiatives

The initiatives listed below are discussed in Sect. 5. Many of these initiatives involve multidisciplinary research that supports more than one of DOE's business areas.

Science and Technology Programs

- Office of Energy Research
  - ORNL as a National Fusion Nuclear Site
  - Radioactive Ion Beams/Recoil Mass Spectrometer/Nuclear Astrophysics
  - Development of Melton Valley as a Strategic Resource for Nuclear and Radiochemical Technology
  - Center for Excellence in Research Reactors (also proposed to the Office of Nuclear Energy)
  - Retention of the Pool Critical Assembly (also proposed to the Office of Nuclear Energy)
  - Biosciences and Biotechnology
  - Computational Biosciences
  - Subsurface Science Research
  - ORNL Genome Program

Energy Programs

- Assistant Secretary for Energy Efficiency and Renewable Energy
  - Oak Ridge Transportation Technology Initiative
- Office of Nuclear Energy
  - Improvement of Safety and Economic Performance of Nuclear Power Plants through Digital Instrumentation and Control

Other ORNL Programs

- Industrial Competitiveness Initiatives
  - Oak Ridge Centers for Manufacturing Technology
  - Environmental Technology Collaboration
  - Intelligent Measurement Systems Laboratory
  - Center for Robotics and Intelligent Systems

5 • Scientific and Technical Programs

ORNL is engaged in basic and applied research and development (R&D) in all of the businesses identified in the DOE Strategic Plan: science and technology, energy resources, national security, environmental quality, and industrial competitiveness. Programs at ORNL frequently address more than one business area, indicating the ability of the Laboratory to integrate its strengths and address diverse challenges that transcend disciplinary boundaries. Some of this work is performed for other federal agencies and for other sponsors.

5.1 • U.S. Department of Energy

5.1.1 • Science and Technology Programs

5.1.1.1 • Office of Energy Research

The Office of Energy Research (DOE-ER) is the largest single sponsor of research at ORNL. It supports programs in magnetic fusion energy, high-energy and nuclear physics, basic energy sciences, and biomedical and environmental sciences. The Advanced Neutron Source also receives funding from DOE-ER.

Magnetic Fusion—AT

The ORNL Fusion Program is distinguished by extensive collaboration, both nationally (with numerous universities, industries, and national laboratories) and internationally (with ten countries), and by the breadth of its component subprograms in physics, technology, and systems studies. Work is carried out primarily in the ORNL Fusion Energy Division, with major contributions from several other ORNL divisions, from the Engineering and Computing and Telecommunications Services organizations of Martin Marietta Energy Systems, Inc., and from the Oak Ridge Y-12 Plant.

The goals of the national fusion energy research program as stated in H.R. 4908—to demonstrate by the year 2010 the practicability of commercial electric power production and to lead to commercial production of fusion energy by the year 2040—will require increasing emphasis on the nuclear aspect of fusion. ORNL is pursuing leading roles in

- the integration of confinement and technology issues needed for understanding fusion physics and for improving the toroidal confinement concept,
- the solution of physics and technology issues for the operation of a toroidal reactor at high duty factor or steady state,
- the attainment of adequate system reliability and maintainability,

- the development of radiation-resistant and low-activation materials,
- the development of a nuclear-capable site for fusion technology R&D, and
- the broader exploitation of technologies and capabilities developed in the fusion energy program and the transfer of these technologies to American industry.

Support for the ORNL program comes from three subprograms in the Office of Fusion Energy (DOE-OFE): Applied Plasma Physics (AT05), which funds theory, atomic physics, diagnostic development, small innovative experiments, and long-range technology; Confinement Systems (AT10), which funds confinement experiments, such as DIII-D and the Tokamak Physics Experiment (TPX), and some applications of plasma technology; and Development and Technology (AT15), which supports nearer term technology and materials research, plasma technology, the International Thermonuclear Experimental Reactor (ITER) project, and systems studies. Support for applications outside fusion comes from a variety of sources both within and outside DOE.

Fusion Theory Program • The primary emphasis of the fusion theory program is on understanding plasma confinement and its limitations in tokamaks, with supporting studies of an alternative toroidal confinement concept—the stellarator/torsatron. Efforts are directed toward applications that improve the U.S. tokamak initiatives (the international ITER effort and the national TPX effort) and that enhance the U.S. and world programs in the stellarator field. Research focuses on the following areas:

- Development of plasma simulation models and computational approaches, and application of models to specific experiments for validation and improvement of the models. This effort includes ORNL's participation in the Numerical Tokamak Project, a Grand Challenge in computational science that is being addressed by a consortium of six national laboratories and five universities.
- Analysis of the anomalous transport of particles and energy, as driven by instabilities and modified by nonplasma effects such as ionization/recombination processes at the periphery. Instability-driven turbulent processes are assessed using simulation models. ORNL has an active role in the national Transport Task Force, which applies theory and experiment to gain a better understanding of transport phenomena in toroidal devices.
- Development of models for instabilities driven by alpha particles, supporting deuterium-tritium (D-T) operations in the Tokamak Fusion Test Reactor (TFTR) at Princeton Plasma Physics Laboratory (PPPL) and preparations for ITER.
- Definition, development, and modeling of plasma fueling and heating techniques, in support of edge physics and divertor performance, helium removal, and pellet fueling.
- Development of large-scale computational models of radio-frequency (rf) heating and noninductive current drive, and development of computational tools and techniques for the analysis and design of rf antennas.

Atomic Physics Program • The experimental atomic physics program, which uses a state-of-the-art electron cyclotron resonance source to study atomic collisions relevant to fusion processes and plasma diagnostics, and the closely coordinated atomic theory program have contributed to the measurement of benchmark systems for testing theoretical approximations; the deduction of trends from studies of isoelectronic, isonuclear, and isoionic sequences; and the finding of new parameterizations for maximizing the predictive power of theory. This progress is expected to continue.

The Controlled Fusion Atomic Data Center provides bibliographic and evaluated numerical data on atomic and molecular processes that are relevant to fusion R&D. A bibliographic database is updated through journal searches by a network of expert consultants, and

recommended numerical data are available in book form and in an internationally accepted electronic format, ALADDIN, through cooperation with the International Atomic Energy Agency. These databases will be made widely available through Internet access. During the planning period, heavy emphasis will be placed on obtaining, analyzing, and publishing the atomic data needed to support edge physics, divertor modeling, and shield and limiter requirements for ITER and TPX.

In the diagnostics development program, a promising laser-based diagnostic for fusion alpha particles is being tested on the Alcator C-Mod tokamak at the Massachusetts Institute of Technology (MIT). Requirements for application to ITER will be developed.

Spherical Tokamak Program • The Spherical Tokamak (ST) Program develops the physics base for low-aspect-ratio tokamaks, tests improvements, quantifies potential applications of the ST to tests of critical fusion technologies (e.g., steady-state divertors and fusion blankets), and clarifies viable future reactor concepts. This research is organized with the following integrated activities:

- Collaboration with institutions active in ST experiments and device design. Experiments include the Small Tight-Aspect-Ratio Tokamak (START) and its upgrade at Culham Laboratory, United Kingdom, and GLOBUS-M at the Ioffe Institute, Russian Federation, which is being designed under an "enhanced" collaboration agreement.
- Experimental initiatives to use existing fusion facilities for testing ST physics, and possibly for testing steady-state divertors, at low cost. New initiatives include the possible use of facilities at ORNL, PPPL, Lawrence Livermore National Laboratory, Los Alamos National Laboratory (LANL), General Atomics, and the University of Texas.
- Studies of a steady-state D-T volumetric neutron source with full noninductive current and a gain of $Q \geq 1$. Such a device would be well matched to the expertise, facilities, and sites available in Oak Ridge.
- Development, jointly with private industry, of small (fusion power of 10–20 MW), fully maintainable ST neutron driver concepts for elimination of fission wastes.
- Development of concepts for a small ST reactor with low capital costs.

Confinement and Technology Program • The main element in the ORNL confinement program has been the Advanced Toroidal Facility (ATF). At the request of DOE-OFE, the ATF device will be mothballed in FY 1995 and the program will be redirected, building on the core competencies of the ORNL fusion program and addressing national program priorities. The core competencies of the confinement program have been identified as

- advanced toroidal confinement physics, especially in the stellarator area,
- edge physics and particle control,
- plasma fueling, and
- rf heating and current drive.

ORNL's role in the integration of physics and technology has expanded during the last three years, and work is in progress to achieve a systematic evolution of capability in support of the DOE fusion program. In the near term, efforts are concentrated in a number of collaborative programs, both national (TFTR, DIII-D, Alcator C-Mod, and LANL) and international [the Joint European Torus (JET), TEXTOR, Tore Supra, and ENEA/Frascati]. These programs focus on techniques for understanding and controlling the plasma boundary, pellet fueling, and ion cyclotron range of frequencies (ICRF) heating and current drive. In the longer term, ORNL has important roles in the ongoing design and R&D for TPX and ITER.

Stellarator Program • For the United States to have a critical low-cost stellarator program, ORNL must maintain its capabilities in this research area. ORNL will continue to

develop the stellarator reactor concept and will provide theoretical and experimental support to the U.S. stellarator experiments at Auburn University and at the University of Wisconsin. ORNL will also play a significant role in selected areas in the international stellarator program, mainly in steady-state particle control, long-pulse heating, and transport studies. Collaborative experiments on Wendelstein VII-AS in Germany, the Compact Helical System in Japan, and the TJ-IU in Spain are already under way and will continue.

Edge Physics and Particle Control Program • The long-term goal of the edge physics and particle control program at ORNL is to develop particle control scenarios for steady-state plasma operation that are relevant to the next generation of tokamak experiments (ITER and TPX). These scenarios cover dynamic control of wall effects, pellet/beam/gas fueling, and controlled exhaust of both the fuel and helium ash. The ORNL program is addressing these issues on existing tokamaks (DIII-D, Tore Supra, and TEXTOR) to develop models that can be used in specifying particle control schemes for future devices

ORNL has a lead role in helium transport and exhaust studies on both DIII-D and TEXTOR and will participate in studies on JET and ASDEX-V. Helium ash removal is a major R&D issue for ITER, and these programs are providing both new data and modeling to improve the helium pumping schemes for future tokamaks. An extensive program of edge physics measurements is in progress on DIII-D, Tore Supra, and TEXTOR with the dual objective of supplying a database for ITER and supporting the validation and application of modeling codes. On TPX, ORNL has the physics responsibility for pumping and gas handling and the lead design role in vacuum pumping.

RF Technology and Experimental Applications Program • ORNL is responsible for the technology development, design, and application of rf power on major fusion experiments, whose systems will in turn provide the development basis for ITER and TPX. The long-range goal of the RF Technology Program is to develop systems that are cost-effective and compatible with operation in fusion power reactors. The technologies are usually prototyped on the Radio Frequency Test Facility (RFTF) or other ORNL facilities to eliminate defects and to test or validate codes at minimum cost. Extensive collaborations play an important role in the development of critical areas such as ICRF current drive, phase control, long-pulse technology and physics, advanced launchers, and advanced heating scenarios. Plans include activities in the following areas.

- ICRF current drive antenna array and phase control systems. The results of fast wave current drive (FWCD) experiments on DIII-D, conducted with an ORNL antenna array, were used in designing a new 8-MW array to be installed this year. Tests of the second-generation phase control system for this array led to a collaboration with the Joint JET Undertaking in which ORNL is responsible for the design of a 32-MW system for JET. ORNL is also developing the real-time matching needed for longer pulse or steady-state machines such as ITER and TPX.
- Long-pulse technology and physics issues. Both the technology of antenna components that can survive long-pulse operation in the plasma environment and the physics base to characterize the plasma response must be developed. Again, collaborations further the state of the art. An ORNL antenna has delivered 54 MJ in 27 s to the Tore Supra plasma; work is under way to improve the Faraday shield configuration and material so that >120 MJ can be achieved. We are designing a third-generation Faraday shield to handle this elevated performance and have extended current drive capability to Tore Supra. The development of this technology is especially important to TPX, since it has a long-pulse/steady-state mission. The Tore Supra collaboration is also being used to measure

how rf power modifies the edge plasma and affects antenna component lifetimes and plasma confinement. Other collaborations supporting this effort involve experiments on TFTR and DIII-D.

- Advanced launcher development and advanced heating scenarios. Waveguide antennas have substantially better power capability and mechanical ruggedness than conventional loop antennas. Using these attributes to full advantage on large (or high-field) machines such as TPX requires innovations such as the folded waveguide (FWG) launcher and a way of removing the linkage between frequency and ion resonance. On the basis of RFTF tests of the FWG, we expect that the injected power density can be extended to >20 $MW \cdot m^{-2}$ (thereby reducing port size). We are using collaborations on TFTR, Tore Supra, and DIII-D to develop direct electron heating techniques, which would remove the frequency link to ion resonances. All of these collaborations support the development of advanced heating concepts and the extension of ICRF heating and current drive to other regimes.

Pellet Injector Technology and Plasma Fueling Applications Program • ORNL is the international fusion community's leading laboratory in developing and applying advanced plasma fueling systems for magnetic fusion. The fueling group is integrated with plasma theory, modeling, particle control, confinement, rf, and edge physics efforts at ORNL and at other fusion laboratories through extensive national and international collaborations (DIII-D, TFTR, JET, Tore Supra, LANL, and ENEA/Frascati). The long-range goal of this program is to develop ultralong-pulse to steady-state pellet injection systems for D-T operation at moderate (≤1-km/s) and high (≥3-km/s) velocities. Applications on experiments are undertaken to demonstrate injector and fueling capabilities. Since no one experiment requires the full range of capabilities, applications are divided among a number of facilities (e.g., tritium at the LANL Tritium Systems Test Assembly, TFTR, and JET; long-pulse operation at Tore Supra). In addition, the program provides specialized injector systems and expertise to support fusion experiments. During the next five years, the ORNL program will concentrate on the following activities, with special emphasis on long-pulse particle control issues.

- Support the successful completion of the TFTR D-T phase with the ORNL tritium-compatible, high-speed pellet injector. The experimental program will focus on ITER-relevant plasma conditions.
- Develop long-pulse to steady-state, reliable pellet fueling systems for TPX and ITER.
- Develop high-speed (3- to 5-km/s) pellet fueling technology for TPX and ITER to provide innovative approaches for improved plasma operating regimes. A key element of this program is the collaboration with ENEA/Frascati to develop a repetitive two-stage light gas gun.
- Develop safe and reliable tritium pellet fueling technology for ITER.
- Install a versatile repeating pneumatic injector on DIII-D as part of an integrated collaboration on pellet-enhanced confinement in rf-heated plasmas, particle control, and edge physics.
- Upgrade the existing Tore Supra centrifuge injector for longer pulses (up to 2-min operation) to study particle control and transport in long-pulse plasmas in which a pump divertor is used for active particle control.
- Define, develop, and implement a tritium fueling capability for the next D-T phase on JET. After completion of the TFTR D-T program, JET will provide the only opportunity to explore physics issues relevant to D-T operations. A new collaboration will build on past collaborations with PPPL and JET in this area.

The ongoing efforts in advanced technology development and hardware applications on large tokamaks are synergistic and result in an integrated approach to the design and fabrication of innovative, capable, and reliable fueling systems for TPX, ITER, and, in the long term, fusion power plants.

Materials Program • The Fusion Energy Materials Program focuses on the development of reactor structural materials, ceramics, and first wall and high-heat-flux materials. Within DOE-OFE, these efforts are supported by the neutron-interactive materials and plasma-interactive materials programs. The ORNL effort supports U.S. participation in ITER, as well as the ultimate objective of fusion as an energy source. The availability of the High Flux Isotope Reactor (HFIR) is essential to progress in the fusion materials development program.

Structural Materials • In the structural materials program, the primary emphasis remains on the qualification of austenitic stainless steels for ITER and the development of low-activation ferritic steels, vanadium alloys, and structural ceramic composites (e.g., SiC/SiC) for a demonstration reactor and future fusion power reactors.

Austenitic stainless steels are the leading candidate for structural materials in ITER because of their advanced state of development and commercial application. In a collaborative program with the Japan Atomic Energy Research Institute, we are investigating the effects of fusion reactor damage levels on the engineering properties of these alloys. Central to this effort is the irradiation of these alloys in HFIR with tailoring of the neutron spectrum to produce damage levels (transmutation-produced helium and displacements per atom) equivalent to those that will be produced in a fusion reactor. These experiments provide data and understanding of radiation response at the temperatures and damage levels required for ITER.

Development of low- or reduced-activation materials is critical to achieving fusion's potential as a safe and environmentally attractive energy source. Our work on low-activation ferritic steels focuses on the most critical or limiting property of this class of alloys: the radiation-induced shift in ductile-to-brittle transition temperature and the resulting reduction in fracture toughness. Our research on vanadium alloys focuses on their chemical compatibility with proposed fusion coolants and the effects of radiation on their fracture toughness.

The effects of irradiation on the dielectric properties of ceramic insulators are of critical importance in the design and operation of numerous fusion reactor systems (e.g., rf heating and plasma diagnostics). We are making in situ measurements of the loss tangent during ionizing radiation and ionizing plus displacive radiation and exploring the phenomenon of radiation-induced electrical degradation (RIED), a rapid, permanent decrease in conductivity following an incubation period. Changes in the loss tangent will affect the choice of materials and the design of heating systems for ITER. RIED could have very serious implications for the selection of materials and the design of systems requiring ceramic electrical insulators.

First Wall and High-Heat-Flux Materials • Research on graphite and carbon-carbon composites is part of the plasma-interactive materials and high-heat-flux materials programs. These materials must exhibit extremely high resistance to thermal shock, erosion, and neutron damage. Optimum thermal shock resistance is offered by appropriately designed carbon-carbon composites (i.e., selected fibers, matrices, and architectures). Current work is directed toward the optimization of these materials for neutron damage resistance.

Advanced Systems Program • The Advanced Systems Program focuses on the definition and conceptual design of future tokamak projects. The conceptual design efforts on TPX and ITER provide the basis for planning on both a national and an international scale.

Both of these initiatives are broadly supported by the ORNL Fusion Program; specific design aspects are briefly discussed here. The Advanced Systems Program is also exploring facilities for testing fusion reactor technology and materials

TPX • ORNL is involved in a partnership with PPPL for the design and construction of TPX. The conceptual design effort is complete, and plans are under way to begin construction in FY 1995. A senior scientist from ORNL, on assignment at PPPL, serves as the Deputy Project Manager, and a department manager from the Energy Systems Engineering organization is one of three engineering managers for the project.

In the physics area, ORNL has a lead role in rf systems, edge physics, and particle control and carries out supporting work in modeling and analysis of fueling, magnetics, and plasma transport. In technology, ORNL's primary areas of responsibility are rf systems, fueling, remote handling, and vacuum pumping.

Engineering design for the rf heating and current drive system will be carried out with support from PPPL and MIT. New concepts for pellet forming and feed systems will be developed for the steady-state fueling system. Development of the remote handling system and integration of maintenance requirements will draw on technology development within the ORNL Robotics and Process Systems Division and ORNL expertise in engineering design and development of remote handling facilities. Requirements for and design of the vacuum pumping system will be closely connected to the edge physics and particle control activity. Responsibility for design and fabrication will be subcontracted to industry, as will much of the total TPX design and fabrication. In several developing areas (e.g., rf and remote handling), industrial partners will be involved early for the purposes of technology transfer.

ITER • ORNL provides the ITER program with expertise in design engineering, physics, plasma technology, fusion materials, and systems analysis. Several ORNL scientists and engineers serve as U.S. ITER Task Area Leaders in areas such as plasma performance, rf systems, containment structures, remote handling, structural materials, and design integration. Several ORNL employees also serve as members of the Joint Central Team.

ORNL expects to continue carrying out a number of ITER-related design (physics and engineering) and R&D tasks. In physics design support, ORNL areas of responsibility are plasma performance and coordination of associated physics R&D within the U.S. base program. In engineering design and technology R&D, primary areas of responsibility include containment structures, remote handling, structural materials, pellet fueling, and rf systems.

Work in containment structures is directed toward key vacuum vessel issues with the goal of establishing a cost-effective approach for design and fabrication. In remote handling, the primary areas include remote cutting and welding, standard component and process development, and tooling. In both areas, U.S. industrial capabilities will be utilized. In structural materials, the primary emphases are qualification of austenitic stainless steel, evaluation of radiation effects on components, and development of vanadium alloys and structural ceramic composites. Proposed ORNL work in pellet fueling includes injector and extruder development and hardware applications for the design and fabrication of a reliable pellet fueling system. In rf systems, key design and development areas are rf insulators, long-pulse Faraday shields, antenna survivability, system reliability, and launcher development. Responsibility for project drawings, computer-aided design and manufacturing, a data management system, and engineering design integration are other important ORNL activities.

International Fusion Materials Irradiation Facility • ORNL staff members have been leading a national design effort aimed at developing a concept for an accelerator-based beam target system for the production of high-energy (14-MeV) neutrons, simulating a D-T

fusion spectrum. This effort has expanded to include international participation in a conceptual design.

The International Energy Agency (IEA) has established an implementing agreement for an International Fusion Materials Irradiation Facility (IFMIF) design activity. Representatives from Japan, Euratom, and the United States have agreed on a mission, design requirements, and a work breakdown structure and have recommended a plan and schedule for a two- to three-year conceptual design. The Russian Federation is expected to join the IEA implementing agreement for the IFMIF activity.

An industrial consortium led by Grumman Aerospace Corporation is under contract to ORNL to provide the engineering design work. The Oak Ridge reservation would be an attractive site for such a facility.

Volume Neutron Source • In 1994, the Advanced Systems Program joined a team led by the University of California at Los Angeles to evaluate the options for a Volume Neutron Source. ORNL is providing support in the areas of concept design and configuration development for improved maintainability and availability. The Spherical Tokamak will also be proposed as a candidate device for the Volume Neutron Source.

Technical and Scientific Applications • The application of fusion science and technologies to problems outside the fusion area has become an increasingly important part of Fusion Energy Division activities and now provides some 15% of the Division budget. Fusion technology has been successfully applied to

- waste remediation using microwaves and cryogenic pellets,
- improved materials production techniques using microwaves and rf waves,
- plasma processing of materials, and
- superconductivity development and applications.

This technology transfer has included work for others (funding through industry and other federal agencies), cooperative R&D agreements, and licensing of ORNL patents to industry. A goal of the Division is to expand these applications by 20% a year over the next few years.

Initiative

Oak Ridge as a National Fusion Nuclear Site

As the nation and the world move toward the goal of developing fusion as an energy source, there is a growing need for the development of nuclear technologies. Both the Joint European Tokamak (JET) and the Tokamak Fusion Test Reactor (TFTR) have demonstrated megawatt levels of nuclear fusion power for short pulses (seconds). Thus, the nuclear technology development phase of fusion is upon us.

The existing major tokamaks are coming to the end of their planned experimental programs. Many of the major facilities planned for the future require a nuclear-capable site. These include the next large tokamak, the International Thermonuclear Experimental Reactor (ITER), which is being planned as an international collaboration; a 14-MeV neutron source for fusion materials development; and the proposed small devices for fusion nuclear technology development.

Our international partners—particularly the Europeans—have already identified suitable sites for these facilities. For example, the bulk of the French fusion effort was moved to Cadarache some years ago, and France now has a fusion infrastructure on a nuclear-qualified site suitable for ITER and other fusion nuclear facilities. In

Germany, a major fusion effort is to be set up at Greifswald.

We recommend that DOE identify a national fusion development site, at which any major future capital investments would be made. This site should also be capable of serving as the U.S. site for ITER. This step would give the United States a competitive position for ITER and for other facilities proposed for international collaboration, such as the 14-MeV neutron source. Operation and management of the site could be conducted in a way that supports major involvement by the private sector.

We propose the consideration of a portion of the Oak Ridge Reservation as a prime U.S. location for the nuclear facilities needed for development of the magnetic fusion energy program. The Oak Ridge Reservation offers a number of sites that could serve this purpose.

The Oak Ridge area is an ideal location for such a site because of the existing scientific and engineering infrastructure in fusion, materials, and nuclear processing, coupled with the availability of the required electrical power, cooling capability, and environmental characteristics. Furthermore, communities in the Oak Ridge area have shown strong support for such initiatives in the past.

High-Energy Physics—KA

The High-Energy Physics Program at ORNL is focused on the study of the properties and interaction characteristics of elementary particles, on detector design and response data for detector collaborations, on radiation shielding design, and on the development of calculational methods that will make possible definitive high-energy transport calculations. The efforts associated with the joint experimental High-Energy Physics Program among ORNL, the University of Tennessee, and other Southern Association for High Energy Physics universities (in particular, Duke University, the University of Virginia, and the University of Mississippi) are expected to continue.

Nuclear Physics—KB

The Nuclear Physics Program emphasizes basic nuclear physics research, both experimental and theoretical, and operation of two user facilities: the Holifield Radioactive Ion Beam Facility, an upgrade of the Holifield Heavy Ion Research Facility that will be operational in FY 1995, and the Oak Ridge Electron Linear Accelerator. Research is carried out at these two facilities by ORNL staff and by visiting scientists from around the world.

Heavy Ion Physics Task—KB02 • The Heavy Ion Physics Task supports research programs in both medium-energy and relativistic heavy ion physics. These programs use accelerator facilities at several laboratories around the world.

The medium-energy research is concerned primarily with the investigation and characterization of the fundamental modes of nuclear excitation. This research program involves the study of the most collective of nuclear excitations: giant multipole resonances. In these studies the resonances are excited using medium-energy projectiles ranging in mass from protons to heavy ions. Each hadronic probe offers a unique selectivity for the excitation of various resonance modes. Of particular importance to these studies is the Coulomb excitation of giant resonances using medium-energy heavy ions. Through Coulomb excitation, both isoscalar and isovector giant resonances are excited with very large cross sections and peak-to-continuum ratios. This work also depends heavily on the measurement of the photon decay from the giant resonances using large arrays of BaF_2 detectors. New directions include

studies of resonance strength in unstable nuclei, produced as beams at high-energy radioactive beam facilities, and a systematic exploration of two-phonon strength involving the giant dipole resonance. Some research effort is devoted to the study of the dynamics of collisions between complex nuclei and the structure of nuclei at high angular momenta and excitation energy.

At higher energies, heavy ion reactions are studied with ultrarelativistic projectiles of 200 GeV per nucleon at the Super Proton Synchrotron, located at the European Laboratory for Particle Physics (CERN) in Geneva, Switzerland. The primary purpose of this research is to study the production and characteristics of the quark-gluon plasma that may be formed in reactions between nuclei at these energies. ORNL plays a major role in the CERN-based WA80 collaboration as well as in the succeeding experiment, WA93. In both experiments, emphasis is placed on photon measurements. Because of their noninteracting properties, photons constitute one of the best probes of early reaction phases. ORNL built the calorimeters of WA80 and continues to operate them. Plans call for a major ORNL contribution to the photon-detection capabilities of WA93 in the form of readout electronics.

If a quark-gluon plasma is formed at the near-threshold energies of the CERN Super Proton Synchrotron, it will be a baryon-rich plasma. In contrast, energies available at the Relativistic Heavy Ion Collider (RHIC) under construction at Brookhaven National Laboratory (BNL) are expected to lead to a relatively baryon-free plasma dominated by created particles. ORNL has a leadership role on one of the two major detectors, the Photon Electron New Heavy Ion Experiment (PHENIX), under construction for the RHIC. This detector emphasizes measurements of electrons, muons, and photons. Because of their penetration properties, the leptons are considered to be excellent probes of the quark-gluon plasma. A certain fraction of muon and electron pairs results from the decay of vector mesons, the properties of which are likely to be a good signal of creation of dense matter and of deconfinement. ORNL is in charge of a major R&D activity, the BNL-based RD-10 experiment, in support of the measurement capability of PHENIX. A cost and schedule review for PHENIX is in preparation.

Initiative

Radioactive Beams/Recoil Mass Spectrometer/Nuclear Astrophysics

The accelerators of the Holifield Facility are being reconfigured to provide a capability for producing and accelerating radioactive ion beams (RIBs). This project, which began in July 1992, is scheduled for completion in FY 1995.

This initiative builds on a long-range plan to provide a world-class center for nuclear structure physics and nuclear astrophysics at ORNL. The beams from the Holifield Radioactive Ion Beam Facility (HRIBF) will provide a unique capability for research. The combination of the existing Oak Ridge Isochronous Cyclotron and the 25-MV tandem accelerator at the Holifield Facility provides the opportunity for producing a large variety of low-energy, proton-rich, radioactive heavy ion beams. The availability of these accelerators and of an appropriately shielded target room for the Isotope Separator on Line source offered a quick, cost-effective method for producing RIBs. Using the tandem accelerator (which was designed to accept low-energy,

negatively charged heavy ions) as the post-accelerator for the facility allows the production of beams of heavy ions up to mass 80. More than 200 new proton-rich compound systems can be produced using stable targets and the beams initially expected from the facility. Many of these are of special interest for studies in nuclear physics and astrophysics.

Parallel efforts are addressing the acquisition of new experimental devices that will allow full exploitation of the new scientific opportunities provided by the RIBs. One such devices is a recoil mass spectrometer (RMS), which will provide the experimental focus for nuclear structure studies. The RMS has been fabricated and delivered to ORNL and will be installed in Robinson Hall.

A large array of high-resolution gamma-ray detectors, with efficiency at least a factor of 10 greater than that of the existing Holifield detector array, is urgently needed as well. This could be realized at a cost of $17 million with the Gammasphere array now under construction at Lawrence Berkeley Laboratory (LBL). DOE has stated that the Gammasphere will be moved to a new site after 18 months of operation at LBL. The HRIBF is one of the two most likely sites for the relocation. However, with the probable schedule for completion, the move of Gammasphere is not expected before FY 1996. Because an improved detection system will be needed in mid-FY 1995 for the RIB studies, it is proposed to upgrade the existing Holifield Close-Packed Array by adding 12 new, larger germanium detector modules to be used in conjunction with 12 of the existing modules (each consisting of a high-resolution germanium detector surrounded by a bismuth-germanate veto detector, with the associated electronics). This upgrade will provide the needed gain of a factor of 10 in efficiency at a relatively modest cost of $1.8 million. As shown in Table 5.1, funds for this upgrade are requested in FY 1995 and FY 1996.

The Nuclear Astrophysics (NAP) program at the HRIBF is a new program established to use RIBs to make pioneering advances in our understanding of novas, supernovas, X-ray bursts, and other spectacular explosive nucleosynthesis outbursts. The goal of the program is to determine quantitative details of these exciting events, such as their time scales, their time-dependent temperature and density profiles, and the abundances of nuclei produced. Because astrophysical models using stable beam studies have been unable to yield even *qualitative* descriptions of such events, our program provides an exciting and long-awaited opportunity for the NAP community.

The ORNL program will be unique, since the HRIBF will be the only U.S. facility able to produce and accelerate high-intensity, low-energy, tandem-quality beams of radioactive nuclei. We will achieve our goals by measuring absolute cross sections of (p, γ) and (α, γ) reactions on proton-rich radioactive nuclei that occur in stellar explosions, exploiting the strong overlap of the required radioactive nuclear beams and HRIBF beams. Measurements will be made with an experimental system centered on a recoil separator acquired from the Nuclear Structure Facility at the Daresbury Laboratory in England. This program will be integrated with stable-beam NAP experiments and on-site theoretical efforts to fully realize the astrophysical implications of our measurements and to guide future work; furthermore, it will have close ties to future neutron-capture NAP studies at the Oak Ridge Electron Linear Accelerator.

Table 5.1
Budget projections by fiscal year for continuing development of the Holifield Radioactive Ion Beam Facility
($ in millions—BA)

	1994	1995	1996	1997	1998	1999	2000
Operating expense	2.9	3.9	4.7	5.4	5.4	5.4	5.4
Capital equipment	1.5	1.0	1.2	0.5	0.5	0.5	0.5
Accelerator Improvement Project	—	0.2	0.8	0	0	0	0

Nuclear Theory Program—KB03 • The nuclear theory effort centers on basic research on low-energy nuclear structure and astrophysics and on relativistic heavy ion physics. The relativistic heavy ion program provides support and guidance for the experimental programs at CERN and BNL and entails calculations with models of hadronic evolution and hadronization. Research in nuclear structure theory takes advantage of the opportunities presented by the joint ORNL–University of Tennessee nuclear structure theory program. This program emphasizes three important themes: (1) the opportunities in traditional nuclear structure physics offered by radioactive ion beam (RIB) physics, (2) the new interface between nuclear structure physics and nuclear astrophysics afforded by RIBs, and (3) the opportunities provided by a new generation of massively parallel supercomputers for both nuclear structure and nuclear astrophysics calculations. Studies in this area include nucleosynthesis, beta decay, numerical simulations of type II supernova explosions, and nuclear reaction calculations for proton-rich nuclei. Part of the theory activities will focus on the computational Grand Challenge on the quantum structure of matter. This project is interdisciplinary in scope and involves collaborations among nuclear, atomic, and condensed matter physics. This research will support a new level of computational nuclear structure physics, primarily to perform algorithm development and support for massively parallel calculations.

Low-Energy Nuclear Physics Program—KB04 • The major task supported by the Low-Energy Nuclear Physics Program is the new program in radioactive beam physics, made possible by the modification of the Holifield Facility to produce RIBs. Funding of $2.4 million has been provided by DOE for this modification. The project's modest cost and short time for implementation were made possible by the presence of the required two accelerators. Light ion beams from the Oak Ridge Isochronous Cyclotron will be used to bombard a thick target to produce nuclear reactions. The resulting radioactive products will be ionized, mass separated, and then accelerated by the 25-MV tandem accelerator. Ions with atomic mass up to 80 will be produced with energies sufficient to undertake programs in nuclear physics and astrophysics. The transition to the Holifield Radioactive Beam Facility (HRIBF) will be completed in FY 1995, and operation of HRIBF as a national user facility, building on the long use of the Holifield Heavy Ion Research Facility, is planned at that time.

To capitalize fully on the potential provided by RIBs, several other tasks are being undertaken in parallel to the RIB project. Chief among these is the commissioning of the recoil mass spectrometer (RMS). The RMS will be housed in a new target room, dedicated in July 1994 as Robinson Hall in honor of Russell Robinson, past scientific director of the Holifield Facility. Robinson Hall will also house a large array of germanium gamma-ray

detectors, such as the Gammasphere now under construction at Lawrence Berkeley Laboratory. The RMS, with a projected cost of $2.2 million, is jointly funded by DOE, ORNL, Oak Ridge Associated Universities, the state of Tennessee, Vanderbilt University, the University of Tennessee, and several other universities. This device has unmatched capabilities for the study of very weakly produced isotopic species and is thus an excellent tool for measurement of RIB-induced reaction channels leading to proton-rich nuclei extremely far from the valley of beta stability. An advanced-design RMS has been fabricated and delivered to Oak Ridge. Assembly is under way, and the RMS will be installed in Robinson Hall.

Most of the low-energy research program is devoted to the study of nuclear structure, nuclear reactions, and nuclear astrophysics with beams provided by the HRIBF. The nuclear structure physics program will extend the studies of nuclear properties to nuclei not now accessible where new phenomena might be observed. We hope to extend data on $N = Z$ systems to the vicinity of ^{100}Sn, exploring, for example, the importance of $T = 0$ pairing. We will probe the proton drip line and extend studies of proton emitters, including possible studies of narrow proton emitting resonances in the continuum and their coupling to bound states. Reaction studies will exploit unique characteristics of transfer reactions provided by light proton-rich beams, and when intermediate-mass ($A \sim 60$) beams are available we will extend investigations of the effects of neutron excess or deficit on fusion near the Coulomb barrier.

The Low-Energy Nuclear Physics Program also supports operations and research at the Oak Ridge Electron Linear Accelerator, a unique pulsed-neutron-source accelerator facility for measurements by time-of-flight spectrometry of neutron cross sections and related quantities over the entire range from 0.001 eV to about 80 MeV. Funding is also provided through this program for related activities, including the evaluation of neutron cross sections for the national Evaluated Nuclear Data Base and nuclear model development.

This program provides both results that are important to basic physics and the bulk of the nuclear data used for applied purposes in the United States. Current basic physics work is focused on improving the value for the polarizability of the neutron, studying the neutron-electron interaction, and developing a research program in nuclear astrophysics. Neutron transmission, differential elastic scattering, and total inelastic, capture, fission, and neutron and gamma-ray emission cross sections can be measured to meet the needs of engineers and scientists who apply nuclear information in their work.

Basic Energy Sciences—KC

The Basic Energy Sciences (BES) Program supports a broad spectrum of research in the physical sciences. The two largest subprograms are Materials Sciences (KC02) and Chemical Sciences (KC03). National initiatives central to this program are the Advanced Materials and Processing Program (in KC02) and the initiative in Advanced Manufacturing (in Engineering and Geosciences, KC04). Key issues facing these subprograms include development of the Advanced Materials Science and Engineering Complex (AMSEC), described in detail in Sect. 4, and the reliable operation of the High Flux Isotope Reactor (HFIR) until it can be replaced by the Advanced Neutron Source (ANS).

Materials Science—KC02 • The Materials Sciences subprogram supports fundamental materials R&D including neutron scattering; synthesis and characterization of new materials; high-temperature materials; ceramic processing; superconductivity; ion beam, laser, and plasma processing; and theoretical studies for advanced energy-related materials.

This subprogram also supports a number of user facilities, including the Surface Modification and Characterization Research Center (SMACRC), the Shared Research Equipment (SHaRE) Program, and the Neutron Scattering Research Facilities at HFIR. These facilities had 341 guest users in FY 1993. Two of the Laboratory's major initiatives are in the materials sciences: ANS and the AMSEC, both discussed in Sect. 4. Funding for the core program is expected to increase during the planning period.

Metallurgy and Ceramics Program—KC02 01 • The Metallurgy and Ceramics Program of the Division of Materials Science (DMS) funds a wide range of research activities in the ORNL Metals and Ceramics (M&C) Division and a New Initiative Project in the Solid State Division. These efforts provide the fundamental framework for fostering the development of innovative materials and processes. The overall goal is to develop an understanding of materials and material processes at all levels, from the atomic structure to the macroscopic properties. The program includes the research components required for better understanding and use of materials: synthesis, processing, fabrication, characterization, and development of models/mechanisms. The R&D effort has close ties to DOE's technology programs, especially the materials-related efforts funded by the Assistant Secretary for Energy Efficiency and Renewable Energy (DOE-EE), the Assistant Secretary for Fossil Energy, and the fusion program within DOE-ER, and to the Nuclear Regulatory Commission. In addition, more than 12 cooperative R&D agreements (CRADAs) with industry have grown from tasks funded by the DMS Metallurgy and Ceramics Program at ORNL.

Research in synthesis and processing science includes the development of fabrication and joining techniques for advanced intermetallic alloys, ceramics, and composite structures. Intermetallics research includes fundamental studies of phenomena related to physical and mechanical properties, ranging from atomic bonding to environmental embrittlement. Investigations in the ceramics program are focused on establishment of basic microstructure-property relationships for the design of advanced ceramics and ceramic composites, including self-reinforced silicon nitrides. Potential future directions in processing R&D include magnetic materials and toughened ceramics for gaseous corrosion protection. A strong first-principles theory effort is integrated with the alloy development program. A preliminary evaluation of capabilities and status of first-principles theory of ceramic materials has been initiated, with the goal of establishing a first-principles effort that complements the experimental program.

The welding and joining program continues to investigate the evolution and stability of microstructures and properties of weldments, including mathematical modeling and experimental verification of transport phenomena. This task includes serving as the coordinator for the national BES Welding Program. With the expansion of the process modeling efforts in the M&C Division, the modeling component of this task has broadened to include the basic component of related solidification modeling efforts, including superplasticity or high rate deformation process modeling. Within budgetary constraints, further expansion of process modeling is planned.

Important to all of the tasks are the development and application of advanced characterization techniques, including analytical electron microscopy, atom probe field ion microscopy, the mechanical properties microprobe, and ion beam techniques. Ion implantation is used to study defect interactions and radiation effects and to modify surface-related properties of polymers and ceramics. New techniques and facilities for high-temperature mechanical properties microprobe studies and the three-dimensional multielement atom probe are near completion. During the past year, orders were placed for a new 200-kV field

emission gun analytical microscope (to replace a 14-year-old instrument) and an advanced analytical scanning electron microscope. An atomic force microscope was added to the mechanical properties microprobe facility. The New Initiative Program funded in FY 1993 involves the study of atomistic mechanisms at interfaces with *Z*-contrast direct atomic imaging and theoretical simulations. The Materials Research and Development Laboratory, part of the AMSEC proposed in Sect. 4, would provide facilities designed for the specific requirements (vibrations, electric fields, etc.) of modern analytical equipment and directly support our characterization efforts.

There is continued increased emphasis on radiation effects, especially in the area of the effects of neutron environments. This program continues to make major contributions to the understanding of mechanisms of reactor pressure vessel embrittlement. In the past year, studies of the HFIR pressure vessel embrittlement have uncovered the likely contribution of gamma irradiation to displacement damage in this pressure vessel and those of similarly configured reactors (e.g., reactors with a long water path between the core and pressure vessel).

Through ORNL and the Oak Ridge Institute for Science and Education, DOE-BES supports the SHaRE Program and the Oak Ridge Synchrotron Organization for Advanced Research (ORSOAR). The SHaRE program gives scientists from universities, industry, and other national facilities access to facilities at ORNL, especially the analytical electron microscopes, the atom probe field ion microscopes, and the mechanical properties microprobe. The ORSOAR program supports an X-ray beam line at the National Synchrotron Light Source at Brookhaven National Laboratory. This facility is used for cooperative research by scientists from more than 20 universities and industrial institutions.

Solid State Physics Program—KC02 02 • The solid state physics program performs interdisciplinary research to advance the understanding of materials and materials-related phenomena that underpin energy technologies. The emphasis is on fundamental problems of national scientific and technological importance in solid-state theory, neutron and X-ray scattering, particle-surface interactions, thin films and interfaces, superconductivity, and the synthesis and processing of advanced materials. The program uses state-of-the-art materials research facilities at ORNL and develops advanced instrumentation and techniques for neutron scattering, synchrotron X-ray and photon research, ion beam and laser processing, and electron microscopy. Unique research facilities in neutron scattering, ion-solid interactions, and synchrotron X-ray research are made available to the scientific community through national user centers that attract more than 300 researchers each year. The program involves extensive interactions with other DOE programs, universities, government laboratories, and industry to broaden and strengthen the research and promote technology transfer.

The solid state theory program develops new theories to explain phenomena in energy-related materials and interacts closely with related experimental programs. Areas of interest include superconductivity, particle-solid interactions, surfaces and interfaces, neutron scattering theory, many-body theory, and magnetism. A new emphasis on atomistic simulations of materials includes investigations of melting, interface structure, and surface kinetics. The program provides essential theoretical support for the experimental solid state program and involves close cooperation with the University of Tennessee (UT) through the ORNL-UT Distinguished Scientist Program and other collaborative arrangements.

The neutron scattering program uses the intense neutron beams at HFIR to investigate the structure and dynamics of condensed matter. Current areas of emphasis include excitations and flux lattices in high-T_c superconductors, magnetic excitations in materials, the structure and thermodynamics of polymer blends, phase behavior in colloidal materials, and

high-resolution residual stress measurements. Extensive improvements to four neutron scattering instruments are under way, and a cooperative program in residual stress involving the ORNL M&C and Solid State divisions has been initiated with joint support from DOE-ER and DOE-EE. Completion of the spectrometer upgrades and the new residual stress instrument will give ORNL unsurpassed capabilities in thermal neutron scattering. Facility use is increasing, with more than 150 researchers using neutron scattering and small-angle scattering instruments at ORNL in FY 1993. The program also provides continuing support to the ANS project.

Increased emphasis is being placed on the synthesis and processing of advanced materials. A new effort in laser-ablation molecular beam epitaxy has been initiated with important implications for the growth of epitaxial superconductors and compound semiconductors. Commercial interest in ORNL's thin-film lithium battery technology remains high, and new materials and composite films for related applications have been synthesized. Fundamental research on glasses and ferroelectric materials is leading to new opportunities in photonic materials. The ion implantation program continues to make progress in the use of ion beams to tailor the surface properties of materials. Research use of ion beam facilities at the SMACRC increased to 93 users in FY 1993, and new work on nanocrystalline and tribological thin films is proposed. All of these activities involve extensive collaboration with industry, including CRADAs on photovoltaic materials, packaging materials for thin-film batteries, thermoelectric materials, varistor materials, MgO crystal growth, plasma processing for submicron metallization, and ion beam processing of ceramic bearings.

Continued development and application of advanced characterization techniques are essential to the solid state physics program. In addition to the neutron scattering instrumentation upgrade described above, major new capabilities in synchrotron X-ray research, electron microscopy, and scanning tunneling microscopy are emerging. ORNL is involved in the development of the UNICAT synchrotron beam line at Argonne National Laboratory's Advanced Photon Source, and support for the MicroCAT beam line is being actively sought. A new 300-kV scanning transmission electron microscope has been commissioned and is providing unprecedented resolution, including the first direct observation of a compound semiconductor sublattice. New electron microscopy capabilities in atomic resolution chemical analysis will be applied to interface studies in a variety of materials. The surface physics program, in cooperation with the ORNL-UT Distinguished Scientist Program, has acquired a unique capability in high-temperature scanning tunneling microscopy (STM). Synchrotron X-rays and photons, high-energy ion beams, STM, and traditional electron spectroscopies will be used to investigate the fundamental properties of metal and alloy surfaces. Superconductivity research will emphasize critical currents, thin-film superconductivity, and materials synthesis and processing. Close interactions with DOE-EE and with industry will be maintained through the ORNL Superconductivity Partnership Program.

Industrial interactions will continue to grow in all aspects of the solid state physics program. Industrial collaborations through CRADAs represent a significant fraction of the research effort. Seven CRADAs are now in place, and four more are under negotiation. This demonstrates significant industrial interest in the program and provides an excellent opportunity to bridge the gap between basis science and commercial applications.

Materials Chemistry Program—KC02 03 • The Materials Chemistry Program focuses modern physicochemical methods on synthesis and characterization of materials, both advanced ceramics and organic polymer systems.

Application of nontraditional synthetic approaches to materials with high-performance optoelectronic and mechanical properties is the central focus of the advanced inorganic materials program. High-dielectric-constant mixed oxides, superconducting oxides, and metal-in-ceramics nanocomposites are emphasized. Preparative methods include sol-gel processing of complex compositions, metal-organic and plasma-enhanced chemical vapor deposition, and morphostatic gas-solid reactions. Tailoring these methods to deposition of thin films on thermally sensitive substrates and formation of fibers and whiskers are of particular interest. Programs explore reaction, transport, nucleation, and growth in precipitation of ceramic precursors and thermodynamics and kinetics of oxide superconductors.

Understanding the relationships among molecular structure, processing conditions, and performance properties of modern organic polymeric materials poses a unique challenge. Techniques being applied include neutron and X-ray scattering for both semicrystalline fibers and largely amorphous polymers and model compounds, neutron spectroscopy, thermal analysis, solid-state nuclear magnetic resonance (NMR) spectroscopy, STM and atomic force microscopy, and molecular dynamics simulations. Used in combination, these techniques are revealing often unexpected microstructural and dynamic features, particularly in the semi-rigid parts of polymer systems. A new theory of polymer interactions is being tested for prediction of compatibility in nanoscale polymer blends; small-angle neutron scattering is the key experimental tool in this work. This polymer research benefits from the presence of an ORNL-UT Distinguished Scientist.

Chemical Sciences—KC03 • The Chemical Sciences Program supports HFIR; the Radiochemical Engineering Development Center (REDC); and programs in atomic physics, chemical energy, separations and analysis, and heavy element chemistry.

High Flux Isotope Reactor • Neutrons from HFIR are vital to many research projects in the materials sciences, chemical sciences, magnetic fusion, and biology programs at ORNL and for users and collaborators from many universities, laboratories, and industries. HFIR offers a unique combination of high flux, a mixed thermal/fission neutron spectrum, low irradiation temperatures, and flux tailoring. It is essential to neutron scattering experiments, isotope production, and studies of material damage and to the design of advanced reactor concepts such as the ANS.

Radiochemical Engineering Development Center • R&D activities at the REDC involve the development and use of production processes and product forms for radioisotopes, predominantly the isotopes of transuranium elements. Transuranium-element isotopes produced at the REDC are used throughout the world for basic physics and chemistry studies of the transuranium elements. They are also used in R&D programs relating to environmental effects, biological effects, and waste isolation.

The DOE Transuranium Element Processing Program, the main program at the REDC, produces and distributes rare isotopes of the transuranium elements, including ^{248}Cm, ^{249}Bk, ^{249}Cf, ^{252}Cf, ^{253}Es, ^{254g}Es, ^{255}Fm, and ^{257}Fm. The sequential process used to produce these isotopes includes (1) fabrication of curium targets in the REDC hot cells, (2) irradiation of the targets in HFIR, and (3) remote processing in the REDC to separate and purify each of the heavy elements and to package the individual products for shipment. Researchers, located primarily at ORNL, Los Alamos National Laboratory, Lawrence Livermore National Laboratory, Lawrence Berkeley Laboratory, and Argonne National Laboratory, use the heavy transuranium elements and their isotopes for R&D in nuclear, organic, and solid-state chemistry; nuclear physics; nuclear medicine; and other areas. The program is sponsored by the DOE-BES Division of Chemical Sciences.

As a coproduct of the Heavy Element Research Program, REDC activities provide ^{252}Cf neutron sources, which can be used in neutron radiography, neutron activation analysis, and cancer therapy. The ^{252}Cf Industrial Sales/Loan Program, sponsored in part by by the Assistant Secretary for Defense Programs (DOE-DP), is carried out to fabricate these neutron sources. Neutron source capsules are fabricated in a variety of configurations and source contents (strengths) ranging from 1 μg to 50 mg of ^{252}Cf. Nearly 240 sources are on loan for uses in medical therapy or research, teaching or demonstration at universities, and industrial applications. About two-thirds of the sources in industrial applications are used by DOE offices or integrated contractors; the remainder are used by other agencies of the federal government. Bulk ^{252}Cf is also supplied to commercial neutron source fabricators. This work is done in the REDC Californium Facility in Building 7930.

Other REDC projects and capabilities include a wide variety of special radioisotope preparations and "hot" experiments in support of existing and future DOE liquid waste pretreatment and management programs. An educational capability exists at the REDC for B.S., M.S., and Ph.D. students in the areas of radiochemistry, accelerator target development, reactor target development, integral neutron cross-section measurement, and radiochemical processing. This capability could be used to enhance efforts of the Seaborg Transactinium Institute in training students interested in transactinium research.

Funding for the major programs currently carried out at the REDC is ~$14 million per year. Of this amount, DOE-ER provides ~55%; DOE-DP, ~43%. The Mark 42 Processing Program sponsored by DOE-DP is described in Sect. 5.1.3.1.

Atomic Physics, Chemical Energy, Separations and Analysis, and Heavy Element Chemistry • The atomic physics program at ORNL encompasses both experimental and theoretical investigations of a broad class of phenomena occurring when multiply charged heavy ions interact with gases, solids, free and bound electrons, photons, and other ions. This program currently operates the EN Tandem Accelerator, a user facility that provides a wide variety of light ions and multiply charged heavy ions at energies up to several million electron volts per nucleon. Members of the atomic physics group are also collaborating on a series of atomic studies with ultrarelativistic heavy ions at the European Laboratory for Particle Physics. At the other end of the energy spectrum, experiments on cross sections for inelastic collisions of multicharged ions with neutral atoms and molecules are carried out at the lowest attainable energies; these experiments are conducted using the ORNL electron cyclotron resonance (ECR) ion source. Studies of collisions of multicharged ions with multicharged ions have been initiated, and a new program is proposed to study details of ion-surface interactions. These studies emphasize characterizing the energy and angular distribution of ejected electrons. The ECR source provides beams for merged-beam experiments. The merged-beams apparatus and the techniques currently being developed are applicable to the study of ion-atom chemical reactions involving unstable or reactive atomic species.

The atomic theory program studies atomic collisions over a wide range of energies using powerful new mathematical and computational methods. Particular attention is focused on complex systems such as highly charged ions, which play a leading role in many branches of energy research. This program interacts strongly with the experimental atomic collision programs at ORNL and other laboratories. Many applications rely on access to supercomputers, notably the CRAYs at the National Energy Research Supercomputer Center and the massively parallel Intel Paragons at the ORNL Center for Computational Sciences, and much effort has been devoted to developing algorithms that efficiently use the features of these architectures. The Center for Computationally Intensive Physics, a collaboration

involving ORNL, UT, and Vanderbilt University, partially supports these activities. This Center is part of a consortium that will use the Intel Paragon, which constitutes a unique resource for theoretical atomic physics. It is interdisciplinary in scope, with collaborations in atomic, nuclear, and condensed matter physics.

Studies of the actinides and transactinides emphasize the heaviest elements that are uniquely produced at the HFIR/REDC complex. The scientific goal is elucidation of the systematic trends in behavior of the characteristic 5f electrons progressing across the periodic table. Experimental approaches to define the chemical and solid state properties of these elements and their compounds include structural studies at high pressures and temperatures, characterization of unusual oxidation states in high-temperature vapors, absorption and luminescence spectroscopic studies of solutions and solids, and magnetic and heavy fermion behavior at low temperatures. New emphases highlight the relevance of this fundamental science to current DOE technological issues in environmental restoration and waste isolation of transuranium materials.

Photochemistry and coordination chemistry related to actinide separations are studied by low-temperature matrix spectroscopy. State-of-the-art relativistic quantum mechanics calculations are carried out to complement experimental studies. ORNL is also involved in a multilaboratory initiative to establish a beam line at the Lawrence Berkeley Laboratory Advanced Light Source dedicated to actinide science; ORNL interest is focused on electronic characterization of gas-phase actinide species.

A major theme of analytical chemistry research is mass spectrometry directed at a wide range of inorganic, organic, and biological materials. Current focus areas include novel ionization methods, including electrospray ionization of complex, thermally sensitive organics and glow discharge ionization of inorganics; ion trap mass spectrometry and gas-phase ion chemistry; precise isotope measurements; biological mass spectrometry; and secondary ion imaging of both inorganic and organic targets. Basic research in laser-based optical spectroscopy places special emphasis on ultrasensitive (single-molecule) fluorescence detection, resonance ionization mass spectrometry, and nonlinear optical phenomena. Recent studies of positron spectroscopy show real promise of providing new approaches to characterizing microstructural aspects of materials; these now make use of the Oak Ridge Electron Linear Accelerator, and a higher intensity positron source is included in plans for the ANS.

A unique array of complementary experimental and modeling techniques is applied to study thermodynamics of interactions and reactions in highly nonideal aqueous solutions of electrolytes at high temperatures and pressures, especially near the critical point of water. The systems studied are selected for their fundamental significance and for their relevance to energy-related technologies including steam generation, nuclear and chemical waste disposal, the extraction of heat and mineral resources, and hydrothermal geochemistry. In fact, many of the existing components of the KC03 basic chemistry program are well positioned to contribute fundamental chemical information that is relevant to the growing national emphasis on environmental quality and associated waste-related R&D, especially for aqueous systems.

Research in surface science–based heterogeneous catalysis gives special emphasis to questions of surface structure and reactions involving sulfur-containing species on clean metals and surface alloys that serve as models for commercial hydrodesulfurization catalysts. Several ultrahigh-vacuum surface structure approaches (including low-energy ion scattering) and surface reaction approaches are employed, including synchrotron-based spectroscopies to characterize molecular adsorbates.

Obtaining new molecular-level knowledge concerning the organic chemical structure and reactivity of coals is an area of continuing emphasis. These studies highlight the application of solid-state NMR techniques to chemically modified coals and the use of surface-immobilized compounds to simulate diffusional restrictions during thermal and catalytic processing of coal. The information derived from these fundamental studies will contribute to the development of novel and environmentally sound processes for the use of coal as a source of liquid fuels, chemicals, and clean energy. The unique methods developed for coal research are being extended to related issues in the thermal processing of biomass.

Chemical and physical principles underlying the design of more effective multiphase separation processes are being defined. The concept of molecular recognition is being applied in the design, synthesis, and evaluation of novel ligands for separating closely related metal ions by solvent extraction. Incorporation of complexing ability, charge-neutralizing ability, and organophilicity into single multifunctional extraction agents is stressed. An emphasis on selective extraction of ion pairs is emerging.

Studies of the photochemical reactions and associated photophysics of aromatic molecules address atypical media such as aqueous solutions and sorbent solids. In addition to elucidating fundamental questions of photoreactivity in anisotropic environments, this work should contribute to understanding the transformation of hazardous materials in natural settings exposed to sunlight.

Research on photochemical reactions and enzyme kinetics is related to chemical energy; studies of transport phenomena in the presence of external fields in multiphase systems support advanced separations processes; and fundamental investigations of the interactions of solvents, solutes, and surfaces aid understanding of supercritical extraction and adsorption.

Initiative

Development of Melton Valley as a Strategic Resource for Nuclear and Radiochemical Technology

The integration of existing, planned, and new process and support facilities in Melton Valley into a focused major nuclear research center can provide support for DOE's long-term nuclear and radiochemical R&D activities. Budget projections for this initiative are given in Table 5.2.

Staff members at ORNL have evaluated the creation of a nuclear research center that can evolve over a 10- to 20-year period to support DOE's long-term nuclear R&D, science, and technology activities. Creation of the Melton Valley Nuclear Science and Technology Center would ensure continued capability to support both DOE Office of Energy Research missions and other crucial research missions at the High Flux Isotope Reactor (HFIR), the Radiochemical Engineering Development Center (REDC), and the Advanced Neutron Source (ANS). Such a center could also play an important role in the education and training of nuclear scientists and engineers.

A detailed assessment of future U.S. nuclear technology needs and the potential capability for such a center to meet those needs has been conducted. This assessment, in conjunction with earlier studies, provides a perspective on the future of nuclear research in the United States and at ORNL. The principal conclusions of the assessment are as follows:

- A wide array of nuclear science activities comprise a very important part of DOE's total programs.
- The broad impact and commercial value of the technologies represented by these activities warrant substantial efforts to maintain existing R&D capabilities, despite the current decline in funding for such work in the United States.
- Over the next 10 to 20 years, the number of facilities and sites at which nuclear research is conducted will decrease significantly and much of the existing capability for producing and handling radioactive materials will be eliminated, owing to reconfiguration of the weapons complex and the phasing out of DOE nuclear research facilities with these capabilities.
- Limited funding will curtail upgrades and restrict needed maintenance of nuclear research facilities, while the effects of aging continue to increase.
- Nuclear research for the next several years will focus on nuclear science and technologies largely unrelated to nuclear power. The capability for future research on nuclear power will be maintained through nuclear science and technology programs conducted for other purposes.

The few major nuclear facilities that will be built in the future will be the natural focal points for new nuclear science and technology centers. ORNL will have one of the most important such focal points in the next century with ANS.

The major existing nuclear facilities in Melton Valley, HFIR and the REDC, form the nucleus of a nuclear center today and would be integrated into the evolving comprehensive center. Existing and anticipated missions for the REDC include production and purification of heavy elements, radioactive waste management R&D, fuel cycle and fission product research, and continued support of some weapons activities for the Assistant Secretary for Defense Programs.

Major planned facilities in Melton Valley include ANS and a complex of facilities for collection, treatment, packaging, and storage of existing and future nuclear wastes. These facilities represent major steps toward the development of a comprehensive center in the rest of this century.

HFIR and ANS represent unique capabilities for the development of new and improved production methods for radioisotopes needed in research, medicine, and industry; for the precommercial production of new isotopes; and for the production of special-purpose rare isotopes. Continuing requests to ORNL for these special-purpose isotopes are indicative of the ongoing needs.

These capabilities require an infrastructure of transportation, target fabrication, postirradiation processing, and waste immobilization and storage facilities. The existing REDC provides the nucleus of this infrastructure, but it must be enhanced and expanded to provide the full support that will be needed.

Nuclear facilities located at the main ORNL site in Bethel Valley provide important programmatic support in inspection of radioactive materials, analytical chemistry, and radiochemical process capabilities, such as limited isotope production. As these older facilities are phased out, some of their capabilities will remain essential to a comprehensive center.

Careful planning to retain capabilities as older facilities are shut down is imperative. For example, two new facilities will be needed early in the next century: an inspection and materials handling facility, with shielded hot cells capable of handling large radioactive hardware, and a general-purpose radiochemical research facility with small shielded cells and glove boxes.

Development of a comprehensive center would optimize the value of the large capital investments already planned in Melton Valley and minimize the additional investment required to sustain the critical inspection and radiochemical process capabilities needed within DOE to support programmatic work. Developing these facilities into a center in Melton Valley would also expedite the location of all of ORNL's hazardous facilities in that valley and away from the central Bethel Valley location.

The Melton Valley center would provide extensive R&D and support to DOE's Assistant Secretary for Environmental Management during decontamination and decommissioning of older facilities. Care must be taken that, in managing existing wastes, the capability to deal with future wastes is ensured.

The center would also enhance the educational opportunities in radiochemistry and radiochemical processes available to the next generation of scientists and engineers.

Table 5.2

Budget projections by fiscal year for the development of Melton Valley as a strategic resource for nuclear and radiochemical technology[a]

($ in thousands—BA)

	1995	1996	1997	1998	1999	2000
Total funding	500	500	1000	1000	2000	2000

[a]Funds are being sought from the Office of Energy Research through Basic Energy Sciences—KC and from the Office of Nuclear Energy through Nuclear Energy R&D—AF.

Initiative

Center for Excellence in Research Reactors

A Center for Excellence in Research Reactors (CERR) is proposed to stimulate increased use of research reactors and to help make these facilities more accessible and user friendly. The CERR will build on strengths in existing research reactor activities at ORNL, other DOE sites, and non-DOE facilities and will benefit both users and operators of research reactors.

The CERR will gather, process, and distribute information about research activities and reactor operations by creating a database on research programs and reactor facilities throughout the United States. In addition, it will serve as a bridge between users and operators of research reactors and act as a catalyst for increasing beneficial interactions among reactor operators.

The CERR has three synergistic objectives:

- Increase the use of research reactors by identifying innovative uses of these facilities and informing prospective users of opportunities available to them at these reactors. It will also promote modifications and/or additions to research reactors to improve their usefulness to users.
- Provide technical support to research reactor users by creating and maintaining a database on user-oriented features. It will also maintain software systems and involve personnel who can perform technical analyses for the users and provide specialist contacts on specific issues.

- Foster excellence in research reactor operations, by stimulating exchanges of "good practices" and "lessons learned" among reactor operators and by encouraging operators to participate in "common element" activities. As an example, the CERR will support interactions between research groups and operational groups (e.g., the Association for Excellence in Reactor Operations) that are focused on promoting excellence in all aspects of operations.

These objectives can be accomplished by a relatively modest effort (less than two full-time equivalent staff members per year) to compile and provide user-oriented information about research reactor facilities and to stimulate mutually beneficial activities within the research reactor community.

Research reactors played a vital part in the development of nuclear science and engineering, and they have been essential to the development of nuclear energy throughout the world. However, more than half of the nearly 100 research reactors built in the United States during the 1950s and 1960s have been shut down. Owing to decreased use during the last decade, inadequate funding for modernization, and more rigorous operating requirements, many others may soon be closed.

The continued rapid loss of research reactor facilities could seriously affect research programs in many technical disciplines. Traditional uses for research reactors (e.g., neutron radiography, activation analysis, medical isotope production, biomedical irradiations, materials studies, and commercial product preparations) are expected to continue. In addition, exciting work remains to be done, including research in advanced ceramics and high-temperature superconductors. Researchers will need facilities that can provide the proper combination of radiation fields, sample space, temperatures, and other parameters.

The decline in the number of U.S. research reactors and the growing need for such facilities in the future present a real national dilemma. In addition, no institutional means has existed for identifying present and projected needs for research reactors and developing an integrated strategy for meeting these needs. As a result, many researchers have no reliable source of information about reactor facilities.

The organization of the CERR would be a positive step toward remedying this situation and reestablishing U.S. leadership in nuclear technology. Specific activities of this program will include

- determining present and future user needs for research reactor facilities;
- collecting, analyzing, evaluating, and maintaining data on existing research reactor facilities;
- developing a unified strategy for establishing and maintaining a viable network of research reactor facilities;
- establishing and maintaining a regional center at ORNL to identify and meet the needs of the user community and to stimulate use of research reactors; and
- establishing and maintaining a regional center at ORNL to promote excellence in all aspects of research reactor operations.

Our aim is to complete the first three activities during the program's first year. In the second year, other regional centers could be established to further increase communications and interactions with the user community.

The CERR should encompass all U.S. research reactors at universities and national laboratories and involve individuals from throughout the nuclear technology community, including representatives of industrial users. The Center will have no operational responsibilities. Owners and operators will remain fully responsible for operating each reactor in compliance with applicable orders or regulations.

ORNL is especially well suited to initiating the CERR because of the Laboratory's strong commitment to excellence in operation of research reactors, established history of providing technical support for reactor users, and proximity to a diverse community of research reactor users. This combination is unique among DOE sites.

The CERR will provide a variety of benefits. The user community will gain easier, more cost-effective access to research reactors. Reactor operators will benefit from increased use of facilities and from cost-effective improvements in operating standards. The CERR will greatly expand educational opportunities for students and for professional staff members of national laboratories, private companies, and governmental agencies; it will also provide an effective channel for transferring technology from government-sponsored research programs to private industries.

Table 5.3 provides budget projections for the ORNL CERR. They are also included in the ORNL budget submission summarized in Sect. 8.

Table 5.3
Budget projections by fiscal year for the Center for Excellence in Research Reactors[a]
($ in thousands—BA)

	1995	1996	1997	1998	1999	2000
Total funding	423	442	482	500	517	534

[a]Funds are being sought from the Office of Energy Research through Basic Energy Sciences—KC and from the Office of Nuclear Energy through Nuclear Energy R&D—AF.

Initiative

Retention of the Pool Critical Assembly

Restarting the Pool Critical Assembly (PCA) at ORNL will support training and education for a number of users, including the University of Tennessee, Louisiana State University, Mississippi State University, DOE, and the Oak Ridge Institute for Science and Education, in support of DOE's science education goals. As outlined in Table 5.4, funding is requested to relocate, restart, and operate the PCA.

The PCA was formerly used to provide hands-on educational experiences for nuclear and military professionals. Its simple, basic structure lends itself to easy comprehension of fundamental reactor principles. Training experiences possible at the PCA include

- hands-on core assembly;
- hands-on reactor startup and shutdown;
- reactivity determinations;
- measurements of the spatial dependence of neutron absorber worth, neutron importance, and power density;
- neutron spectral measurements; and
- neutron activation analysis.

PCA-enhanced training programs will increase the professional capabilities of nuclear engineering students and nuclear specialists (e.g., DOE reactor operations professionals and industry personnel).

It is proposed to relocate the PCA to Building 7930 of the Radiochemical Engineering Development Center (REDC). The fuel and core assembly will occupy a 2.4- by 3.6-m (8- by 12-ft) area in the north end of an existing californium storage pool. A 110-m^2 (1200-ft^2)annex will be needed to house training facilities, work areas, and the

PCA control room. General plant project (GPP) funding will be requested for the control room annex.

The restart plan will contain a work breakdown structure detailing all tasks required for restart. Restart activities will require funding in FY 1995 and FY 1996. After restart in FY 1996, operations will require about $300,000 annually, part of which will be provided by the HFIR training section. The PCA will become a part of the REDC complex. However, REDC will not provide any funding, and a fair share of utility usage and pool demineralization costs will be paid by the PCA.

Table 5.4
Budget projections by fiscal year for Retention of the Pool Critical Assembly[a]
($ in thousands—BA)

	1995	1996	1997	1998	1999	2000
Total funding	568	705	300	300	300	300

[a]Funds are being sought from the Office of Energy Research through Basic Energy Sciences—KC and from the Office of Nuclear Energy through Nuclear Energy Research and Development—AF.

Engineering and Geosciences—KC04 • The major effort sponsored by the engineering component of the Engineering and Geosciences Program is the Center for Engineering Systems Advanced Research (CESAR). CESAR will continue fundamental research in intelligent machines, specifically in the areas of cooperation among multiple robots, sensor-based mobile manipulation, and learning for sensory motor control systems. Results from this core research program will continue to have significant ramifications for a number of applications and applied programs, including those focusing on environmental restoration and waste management and emerging programs in support of advanced manufacturing initiatives, as well as information processing activities. CESAR will play a key role in the Center for Robotics and Intelligent Systems, which will be established to enhance the transfer of new developments in robotics technology to the private sector, as described in Sect. 5.1.6.5.

The CESAR facilities include a state-of-the-art high-performance computing environment; numerous sensor systems, including multispectral vision sensors and laser range cameras; robot manipulators; and several mobile robots, some custom-built at ORNL (the HERMIES series and the new holonomic platforms) and others commercially available but customized at CESAR with sensors and computer control. The DOE-BES investment is being leveraged and augmented by support from a number of sponsors that target various applications of robotics and intelligent systems. Advanced intelligent machine and robotics technology development is being performed using the CESAR facilities and expertise for a large multilaboratory program in robotics for environmental restoration and waste management, funded by the Assistant Secretary for Environmental Management. CESAR is teaming with the efforts at the Oak Ridge Centers for Manufacturing Technology, focusing on technologies enabling agile manufacturing. The DOE Office of Health and Environmental Research supports informatics and computational biology R&D that focuses on pattern recognition, database design and management, and data analysis and interpretation for genome-related applications.

Non-DOE sponsors include the Department of Defense and the National Highway Transportation Safety Administration. The Office of Naval Research provides support for the

Center for Neural Engineering. Tennessee State University (TSU), a historically black university in Nashville, Tennessee, is the lead organization for this center, which encompasses a pioneering teaming arrangement among TSU, ORNL/CESAR, Meharry Medical School in Nashville, and Accurate Automation Technologies, a high-technology company in Chattanooga, Tennessee. The center makes use of the special CESAR facilities in robotics and intelligent systems to provide research and educational experiences to faculty and graduate students from the consortium participants. Efforts to apply CESAR expertise to new initiatives in advanced manufacturing are under way.

CESAR R&D activities continue to show results in the technology transfer arena. Work on controlling a new robot wheel mechanism that allows for omnidirectional and holonomic mobility won one of the prestigious R&D 100 awards in 1993.

The Geosciences Research Program focuses on the fundamental geochemical processes that control matter and energy transport in the earth's crust. These efforts contribute directly to the exploration for and exploitation of oil, gas, and geothermal energy deposits, to our understanding of the fate of anthropogenic inputs into the environment, and to the management and remediation of toxic and radioactive wastes. Unique facilities and capabilities are developed and used in studies of the thermochemical properties of gases in the system H_2O-CO_2-C_xH_y-H_2-N_2; the nature of fluid-rock-soil interactions as constrained by the distributions of the naturally occurring stable isotopes of H, C, N, O, and S in fluids and solids; the solubilities of natural and man-made materials in subsurface brines, the geochemical controls on elemental transport, and the subsurface lifetimes of natural and synthetic organic compounds over wide ranges of temperature and pressure; and the effects of fluid-rock-soil interactions on elemental transport and fluid flow at the scale of pores and grain boundaries using advanced analytical approaches. New acoustic imaging techniques for subsurface and magmatic environments are being developed.

Advanced Energy Projects—KC05 • The Division of Advanced Energy Projects (AEP) supports exploratory research in materials and chemical sciences at moderate levels; the typical project duration is three years. ORNL projects currently include electric-field-driven reactors to fabricate ceramic precursors, the investigation of enzyme hydrolysis mechanisms for energy-efficient waste management and bioprocessing of cellulose products (e.g., wastepaper), and novel composite ceramic coatings for high-temperature friction and wear control. Throughout the fiscal year, projects with truly innovative research focuses are proposed for support through the AEP program.

Applied Mathematical Sciences—KC07 • The Applied Mathematical Sciences Program supports research in parallel processing algorithms; tools to facilitate the use of parallel and distributed computing systems; and the development of applied mathematical, statistical, and computational methods for analyses of physical processes. These research activities are supported by an Advanced Visualization Laboratory and an Advanced Computing Laboratory. The Advanced Visualization Laboratory maintains state-of-the-art visualization capability for scientific research collaborations and explores enabling technologies. The primary parallel computer in the Advanced Computing Laboratory is an Intel iPSC/860 supercomputer with 128 processors and a peak rating of 7.6 gigaflops. The resources of the ORNL Center for Computational Sciences (CCS) are used, as appropriate, to accomplish the research objectives of the Applied Mathematical Sciences Program.

The following will continue to be major research areas: computational techniques and tools for solving Grand Challenge problems, heterogeneous distributed computing, algorithms and software for advanced computer architectures, performance characterization and

evaluation of parallel computers and programs, and mathematical modeling of environmental and engineering problems and their numerical solution on parallel computers. Specific emphasis is placed on sparse and basic matrix computations, data analysis, design and analysis of computational experiments, and the analysis and numerical solution of partial differential equations. Areas of increasing emphasis include high-speed communication and networking, multimedia collaboration and reports, large-scale data analysis and visualization, data storage, computational steering, application parallelization, and information databases. Pervasive in this research is the requirement for parallel processing and related software tools to meet the computationally intensive needs of today's computer models.

The Grand Challenge research being conducted as part of the national High-Performance Computing and Communications (HPCC) Program is heavily dependent on the KC07 program. For example, the groundwater modeling Grand Challenge problem relies on the expertise developed in the Applied Mathematical Sciences Program for developing new codes and algorithms on parallel computers that allow greater complexity in both processes and scale for use in evaluation of remediation strategies. The first-principles simulation of materials properties Grand Challenge requires the use of sophisticated numerical techniques that scale up to enable simulations involving thousands of atoms. The Computer Hardware, Advanced Mathematics, and Model Physics (CHAMMP) program, a DOE initiative in atmospheric and climate research (funded through the carbon dioxide research program—KP05), benefits from the basic program in KC07 in that it requires new parallel computing research in numerical methods, software tools, software engineering, statistical analyses, data storage, and visualization.

The CCS is one of two High-Performance Computing Research Centers established as part of DOE's contribution to the national HPCC Program. The CCS has the following responsibilities:

- Research in two "Grand Challenge" areas: (1) groundwater transport and remediation and (2) materials simulation, plus provision of computing resources to Grand Challenge groups in global change as represented by the CHAMMP program, quantum chromodynamics, computational biology, computational chemistry, the Numerical Tokamak Project, and the quantum structure of matter and to users of the National Energy Research Supercomputer Center.
- Provision of a computing center capable of meeting program requirements, using massively parallel processing (MPP) computers.
- Evaluation of developing computing systems, procedures, and architectures.
- Development and provision of advanced networking.

The CCS Management Plan has been approved by DOE's Office of Scientific Computing.

The research programs of the CCS are carried out in the main by the Partnership in Computational Science (PICS) consortium established for this purpose. Members of the PICS consortium, in addition to ORNL, are DOE's Ames Laboratory and Brookhaven National Laboratory; the State University of New York at Stony Brook; the University of South Carolina; the University of Tennessee at Knoxville; Rice University; and Texas A&M University. The programs of the CCS are closely coordinated with those of the second DOE HPCRC, the Advanced Computing Laboratory at Los Alamos National Laboratory (LANL), to ensure the success of the HPCC initiative.

Because the calculations and modeling needed for the Grand Challenge problems demand, and in some circumstances exceed, the state of the art, the CCS computers must represent the state of the art. The computing plan features a sequence of Intel Paragon XP/S

computers; the XP/S 5 and the XP/S 35 (in the designation XP/S *n*, *n* represents the nominal peak speed in billions of floating point operations per second, or gigaflops) are currently supporting Grand Challenge research for the CHAMMP project and the materials simulation and quantum chromodynamics groups. The next computer in the planned sequence, an XP/S 150, is scheduled to be added in February 1995. The CCS also includes a Kendall Square Research KSR1-64 machine, for users interested in a shared memory platform. To maintain the forefront computing character expected of the CCS, we intend to carefully assess the directions of supercomputing over the next year and propose to DOE the upgrade of our computing capability to beyond 600 gigaflops toward the end of FY 1996.

To ensure the availability of reliable computing resources to Grand Challenge users, the CCS includes a user services staff, in addition to an operations and administrative staff. Intel participation takes place through a CRADA that supports the full-time presence of three parallel systems engineers.

The storage and backup requirements for the CCS computers are demanding and will become more so as the power of these machines continues to increase. The CCS and the Atmospheric Radiation Measurement (ARM) Program are developing a multiterabyte, high-performance file storage system that will house a complete data archive for the ARM Program (see Sect. 5.1.6.2) and meet the data archival needs of the CCS (projected at 15 terabytes in FY 1995). The cost of the archive will be shared between the ARM project and the CCS, based on the storage requirements of each. Capital requirements include devices providing capability to perform system backups effectively and with reasonable speed and to offload large files from the Paragon systems to a backup tape device.

The CCS Evaluation of Developing Systems Project investigates new and experimental computer systems, focusing on innovative hardware and software features, to evaluate their suitability for Grand Challenge applications and to provide feedback to machine architects, system software designers, and application programmers. With the ORNL Engineering Physics and Mathematics Division, the CCS is concentrating on three areas:

- Storage, with emphasis on solutions to the massive data storage and archive needs of the Grand Challenges and investigating the integration of large, multimedia databases into a distributed computing environment.
- Visualization, with emphasis on the viability of interactive visualization of Grand Challenge output, allowing researchers to ask "what if?" and then steer the simulations to interesting solutions. We will evaluate the use of multimedia to explore massive data sets as a means of discovering interesting, important and perhaps subtle scientific phenomena.
- Computing, with emphasis on the performance and capabilities of the next generation of hardware for distributed computing, especially the effective use of large distributed databases and network transfer problems.

The Evaluation of Developing Systems Project includes a laboratory with the capabilities to explore innovations in networking that will move us into the gigabit per second region and beyond. Recognizing that first-quality networking is the key to many aspects of our computing and communications future, we also emphasize the availability of "operating" networks for the CCS and for our PICS and CHAMMP participants.

The Engineering Physics and Mathematics Division and the CCS intend to set up an experimental, high-speed network between ORNL and LANL, with the aim of creating a heterogeneous, distributed supercomputing system, made up of the Intel Paragons at Oak Ridge and the Thinking Machines CM5 at Los Alamos. We are pursuing and contemplating additional important networking experiments and strategies.

Industrial participation is a central feature of the HPCC Program and the CCS. We have strong ties with the computer industry. Through broad efforts, particularly in the ORNL Metals and Ceramics Division, the CCS has established a wide range of cooperative projects with industry.

These projects have led to the creation of the Computational Center for Industrial Innovation (CCII), a DOE Industrial User Center. The CCII will be the ORNL focal point for cooperative computational projects, with a charter that includes opportunities for extended-term, large-scale cooperative projects as well as initiation forays with organizations exploring new territory. A leading-edge visualization environment will be a key component of the CCII.

ORNL's plans for computational science and use of computing tools are summarized in Sect. 7.3.1.

Energy Research Analyses—KD

ORNL provides support to DOE-ER in technical and economic assessments of alternative energy sources for selected sectors of the U.S. economy. The funding level varies according to the specific needs of DOE but is expected to remain relatively stable. Future technical and analytic support for assessments will be provided as requested. ORNL anticipates providing support for analysis of global climate change issues and new analyses in support of the National Acidic Precipitation Assessment Program.

Advanced Neutron Source—KE

The Advanced Neutron Source is described in Sect. 4.1.

Biological and Environmental Research—KP

Goals of the Biological and Environmental Research Program are to (1) study the interaction of energy-related physical and chemical agents with living organisms and the environment, including their transport, chemical transformations, adverse health effects, and ultimate consequences to humans and the environment; (2) map and sequence mammalian genomes; (3) contribute to DOE's Nuclear Medicine Program and other beneficial applications programs; and (4) transfer research findings and technological developments to the private sector. Research areas in biology include mammalian genetics, molecular genetics, protein engineering, cell biology, carcinogenesis, macromolecular structure, mutagenesis, and risk assessment. Environmental science research covers biogeochemistry, environmental biotechnology, global environmental chemistry, ecosystem studies, geosciences, hydrology, and environmental assessment. Health sciences research encompasses human health analysis, epidemiology, health assessments, radiation and chemical physics, dosimetry, nuclear medicine, and instrumentation development for sensitive detection and monitoring of chemicals. Two unique user facilities contribute to the ORNL Biological and Environmental Research Program: the Oak Ridge National Environmental Research Park and the Bioprocessing Research Facility. Users of these facilities include staff members from national laboratories and industry and students and faculty members from universities. Construction of the Center for Biological Sciences, described in Sect. 4.2, would enhance all of these activities.

The ORNL Biological and Environmental Research program is one of the broadest multidisciplinary life sciences research programs in the nation and covers a diverse range of

basic and applied studies. This program is expected to experience growth in several areas during this planning cycle, including global change research, subsurface sciences, protein engineering, human genome research, and structural biology. Initiatives in bioscience and biotechnology and in computational biosciences, both cutting across all elements of the ORNL program, are proposed.

Initiative

Bioscience and Biotechnology

ORNL has created a Center for Biotechnology to provide a more coordinated focus for the Laboratory, to increase its performance effectiveness, and to enhance the development of collaborative multidisciplinary efforts among ORNL divisions and between ORNL and other institutions, both private and public, throughout the world.

Biotechnology is an integrating science that emphasizes the development and application of biological approaches to meet national needs in health and environmental protection, biomedical applications, environmental remediation, pollution abatement, and energy production. ORNL is uniquely positioned to assume national leadership in this field owing to its diversity of interactive disciplinary foundations (e.g., biology, biochemistry, bioengineering, and biophysics) and its core competency in biological and environmental science and technology. The establishment of the ORNL Center for Biotechnology reflects the importance that the Laboratory places on research, development, and application in this field and the increasing national and international emphasis on biotechnology. Biotechnology activities can be divided into three broad areas: biomedical, bioprocessing, and environmental.

Biomedical research is directed at providing an improved understanding of the human genome and better, less expensive biomedical technology.

In genome research, mouse genome studies provide models for understanding the human genome in terms of genome structure/function relationships and the basis for hereditary human diseases, such as cleft palate, polycystic kidney disease, and sickle cell anemia. Cryopreservation of sperm and embryos of mice allows valuable mutants to be preserved at low cost.

A computer system makes it possible to submit raw DNA sequences to ORNL by electronic mail (e-mail); the positions of introns and exons are predicted by GRAIL, ORNL's Gene Recognition and Analysis Internet Link program, and the results are returned by e-mail in only a few minutes with a comparison of assembled exon sequences to sequences in the international databases. ORNL also publishes the *Human Genome News* for DOE and the National Institutes of Health (see Sect. 5.1.6.2); this publication is electronically distributed to an international audience.

A strong structural biology program focuses on genome analysis using X-ray and neutron diffraction, three types of mass spectrometry, several forms of scanning probe microscopy, and electron microscopy with holographic analysis. Protein engineering of human growth factors is determining the essential structural features for activity.

In ORNL's nuclear medicine program, radiopharmaceuticals are designed and synthesized to deliver radioactive isotopes to targeted disease sites in the human to make tumor inactivation and diagnosis as specific as possible.

In the biosensor area, the development of an award-winning endoscope allows the use of laser light to identify cancerous regions of the human esophagus with near

100% reliability. Efforts are under way to extend this technique to other organs.

The Oak Ridge Center for Healthcare Industry Development (see Sect. 5.1.6.4) focuses on biomedical R&D through outreach to the medical community and industrial partners. It is integrated into the Center for Biotechnology.

Bioprocessing uses living organisms or their viable fractions to produce new products; it is the critical link between fundamental science and innovative industrial application. ORNL has been engaged in bioprocessing for more than 25 years. Industrial applications of bioprocessing have had an impact in fossil energy, chemical processing, fermentation, environmental control technology, agriculture, and biomedical advances.

In support of ORNL's expanding role in bioprocessing, the Laboratory has established the Bioprocessing Research and Development Center (BRDC). A major emphasis is on bioprocessing systems that can economically produce fuels and chemicals from renewable feedstocks, including the use of appropriate waste materials. Other important BRDC activities are the development of techniques for less energy-intensive bioprocessing of petroleum and coal and systems for the degradation or removal of process pollutants. In addition, solar-energy-driven bioprocesses are being studied for production of fuels and chemicals via routes such as carbon dioxide use and recycle.

The approach in BRDC programs is to use fundamental scientific and engineering concepts as the basis for advanced processing systems that provide order-of-magnitude improvements in bioprocess technology, demonstrate technical feasibility of the advanced systems, and establish industrial interactions as a means of technology transfer. BRDC programs include activities in applied biosciences research (biophotochemistry, enzymology, microbiology), bioengineering R&D (advanced bioreactors, biocatalysis, bioseparations), and bioprocess engineering (bench and pilot-scale operations, off-site demonstrations, and technology transfer).

Environmental efforts focus on the application and use of molecular biology for environmental issues. Development of biological markers is an ongoing effort that enables evaluation of environmental health through use of a series of molecular measurements that enable predictions at population level. These tools have been used to aid Greenpeace and the Canadian government in evaluating the cause of the demise of the beluga whale population in the St. Lawrence Seaway; they have also been transferred to the Netherlands for incorporation into that country's marine monitoring program.

Bioremediation research is concentrating on in situ cleanup of organics. Studies have been conducted at DOE's Savannah River and Hanford sites, and plans are being formulated to work with General Motors (GM) and Ford on a GM site. Efforts are generally directed toward enhancing natural microbes; however, a program for releasing genetically engineered microorganisms has recently been initiated with the University of Tennessee.

Budget projections for programs in biotechnology are presented in Table 5.5.

Table 5.5
Budget projections by fiscal year for Biosciences and Biotechnology
($ in millions)

	1995	1996	1997	1998	1999
Total funding	67	69	71	73	77

Initiative

Computational Biosciences

Rapid advances in computer technology and computational sciences are having a major impact on the biological sciences. The integration of the tools of computational science into both the practice and the communication of the biological sciences is revolutionizing our understanding of the biological world. Within the next few decades, we may well be able not only to predict the three-dimensional structure of a protein from the DNA sequence of its gene, but also to make reasonable inferences about its function in the organism from which it was isolated. Increasingly sophisticated models of the local, regional, and global environments will allow us to more accurately predict the impact of human actions on the biosphere.

Computational bioscience, an interdisciplinary field focusing on the application of high-performance computing technology to modeling, analyzing, and displaying the underlying behavior and physical principles of biological systems, will have a major impact on these and other areas. It offers a number of advantages over the independent use of traditional R&D methods in either computational science or biology by

- using advances in high-performance computing to study biological problems in ways that complement traditional experimental techniques;
- extending the realm of biology to include the modeling and simulation of complex systems whose analysis is beyond the scope of standard experimental techniques;
- permitting more timely solutions, through the use of mathematics, computing, and physical principles, to problems in many areas of biology that are now limited by the inefficiency of even the best experimental investigations; and
- using new tools for analysis and visualization, allowing for otherwise unattainable insight into complex data.

Computational areas with immediate biological impact include data visualization, pattern recognition, simulation, data communication (e.g., networking), databasing, data acquisition (including imaging), virtual reality, artificial intelligence, expert systems, and chaos/fractals. Bioscience areas being affected by computational sciences include environmental modeling (climate, ecosystem, population), biological systems analysis and modeling (organismal, biochemical), anatomy, medicine, developmental biology (analysis and imaging), structural biology, protein engineering, molecular dynamics, drug design, genome analysis, and biokinetic modeling.

ORNL and DOE have a variety of resources that can be applied to computational biosciences. A key resource for this initiative is the ORNL Center for Computational Sciences, which has goals (e.g., complex data visualization) that overlap computational biosciences. Other resources at ORNL include capabilities and expertise in

- genetics, genome research, protein engineering, molecular biology, neuroscience, and biotechnology;
- X-ray, neutron, and computational macromolecular crystallography;
- artificial intelligence, expert systems, and supercomputing;
- molecular dynamics modeling;
- population and ecosystem dynamics;
- landscape pattern and process analysis;
- global dynamics and critical environmental pathways modeling;
- biokinetic modeling of radioisotope and chemical behavior in the human body;

- risk analysis and biostatistics; and
- model validation and error and uncertainty analysis.

Given the local infrastructure, the capabilities of ORNL's scientific staff, and the types of issues under the computational biosciences umbrella, it is apparent that ORNL can play a key role in many computational bioscience challenges, including

- protein modeling,
- genome analysis,
- DNA modeling,
- computational neuroscience,
- environmental modeling,
- complex data visualization,
- determination of macromolecular dynamics/structure, and
- biomedical simulations.

An infrastructure for computational biology has been established through a project funded by the Laboratory Directed R&D Fund. This project provides a mechanism for researchers in several divisions to interact productively and develop computational tools and technologies that benefit ORNL and the larger research community. It also supports the development of several interdisciplinary technology focus areas. One area—high-performance computing for protein function, catalysis, and structure prediction and characterization—will have a significant positive impact on the human genome project, structural biology, computational Grand Challenges in rational protein design and drug design, catalysis, and biotechnology. Other technical focus areas (e.g., internal biokinetic dosimetry and anatomical modeling, individual-based population modeling, and medical applications for high-performance computing) will also be pursued.

Funding is being provided by DOE's Office of Health and Environmental Research; additional funding is being sought from other sponsors. Table 5.6 provides a summary of the anticipated funding.

Table 5.6
Anticipated funding by fiscal year for the Computational Biosciences initiative
($ in millions—BA)

	1994	1995	1996	1997	1998	1999
Operating	2.1	2.2	2.3	2.4	2.5	2.7
Capital	0	0.2	0.3	0.5	0.5	0.3

Analytical Technology–Dosimetry Research and Measurement Science—KP01 • We are developing relationships between radiation exposure and dose by modeling the biokinetics of radionuclides within the body and the deposition of ionizing energy within radiosensitive tissues from these radionuclides and from radiation outside the body. Exposure-dose relationships compose the cornerstone of radiation protection and play an important role in the evaluation of medical diagnostic procedures that involve the use of radiopharmaceuticals and X-ray machines.

Models describing the biokinetics of radionuclides explicitly depict, as far as is practical, the tissues and physiological processes controlling the movement or retention of radionuclides in the body. This approach allows (1) incorporation of basic physiological information into the model, (2) realistic treatment of decay products formed in the body, (3) meaningful extrapolation of data from laboratory animals to humans, (4) meaningful analogies between an element of interest and physiologically similar elements, and (5) a linkage between excretion of a radioactive element and its movement in body tissues and blood.

The scientific expertise in this program is demonstrated by the extensive participation of ORNL staff on committees and task groups of the National Council on Radiation Protection and Measurements, the Medical Internal Radiation Dose Committee of the Society of Nuclear Medicine, and the International Committee on Radiological Protection. This activity also involves multidisciplinary research aimed at three major areas: cost-effective chemical and biological screening techniques, biological and chemical sensors, and basic technical advances of emerging monitoring technologies.

Passive radiation dosimeters based on alpha track and electret detectors are being applied with considerable success to in situ monitoring of alpha contamination. Targets include both indoor surfaces that are difficult to access and soils. An in situ spectroelectrochemical surface-enhanced Raman sensor, being developed primarily to detect chlorinated aliphatics in groundwater, can detect nicotine and alkaloid metabolites at trace levels. Direct measurements in biological fluids are possible.

By combining fluoroimmunosensor (FIS) technology with a capillary reagent delivery system, we have constructed microscale sensors that can repetitively perform a variety of FIS procedures, remotely or in situ. These procedures include adding a solid- or liquid-phase antibody, adding secondary reagents (e.g., the labeled "second" antibody when performing sandwich assays), and rinsing to remove unbound impurities. In addition to delivering reagents, the microscale regenerable sensor can sample analytes through a membrane or a porous microcavity, via either diffusion or aspiration. The latter mode of sampling could be very beneficial in the eventual use of the sensor to measure large molecules.

Another instrument being developed is a portable synchronous luminoscope for low-cost field screening of polychlorinated biphenyls (PCBs). Such a device is being field evaluated by the U.S. Environmental Protection Agency for field screening luminescent organic pollutants.

ORNL researchers are internationally recognized for their expertise in neutron dosimetry. International personnel neutron dosimetry intercomparison studies, conducted annually at the Radiation Calibration Laboratory (RADCAL), are a major focus of technology transfer. RADCAL is equipped with radioisotopic sources and an X-ray machine configured to deliver precise doses at specific locations. The major emphasis of the research is on personnel radiation dosimetry, but RADCAL is also involved with nuclear accident dosimetry, radiobiology research, national dosimeter performance test programs, teaching and training activities, and dosimeter intercomparison studies that include beta, gamma, and X-radiation as well as neutrons.

A broad-based program in the ORNL Health Sciences Research Division is directed toward increasing our knowledge of detrimental effects of all types of energy production. Included in this program are research on chemical, biological, and physical agents associated with energy technologies; development of advanced measurement techniques; and development of appropriate assessment and risk analysis methodologies needed to make balanced evaluations of current and future energy strategies.

Environmental Research—KP02 • The goal of the environmental research program is to increase our understanding of the transport, transformation, and effects of energy-related contaminants in the environment. To gain a greater appreciation of the fundamental biological, chemical, and physical processes governing the transport and effects of materials in the environment, we emphasize linkages among the atmosphere, the terrestrial biosphere, and freshwater systems.

Environmental Biogeochemistry • The ORNL atmospheric research project concentrates on quantifying several aspects of atmosphere/biosphere exchange that are critical in understanding and predicting the effects of global change. These include wet and dry removal processes and surface emission rates of both natural and pollutant constituents important to tropospheric chemistry and biogeochemical cycling. Major emphasis is placed on determining the interactions of these materials with forest canopies, particularly in complex terrain. Projects include testing and application of throughfall methods for quantifying terrain and canopy controls on deposition in mountain forests and developing and testing methods and models of mercury vapor interactions with land and water surfaces. This work supports DOE tasks in the areas of dry deposition, precipitation scavenging, deposition modeling, landscape scaling, biogenic emissions, and biogeochemical cycles.

Transport studies involve the measurement of naturally occurring radionuclides (^{3}H, ^{7}Be, ^{35}S, and ^{210}Pb), anthropogenic radionuclides (^{137}Cs, ^{239}Pu, and ^{240}Pu), and stable isotopes (^{2}H, ^{13}C, ^{15}N, and ^{18}O) to trace and quantify the dispersal and fate of energy-related materials, as well as fixed carbon, in watershed, estuarine, and ocean-margin systems. The watershed research is focused on identifying groundwater and surface water sources and on quantifying the extent to which atmospherically derived substances (e.g., sulfur and lead) biogeochemically interact with drainage-basin soils and vegetation during runoff or snowmelt. The marine research focuses on using biogeochemical tracers to quantify the exchange of materials between land and sea, between continental shelf and slope, and between sediments and water column. Planning and scientific exchange between the Institute of Energy Problems and Chemical Physics and the Institute of Oceanology of the Russian Academy of Sciences and ORNL are aimed at developing a joint research program to investigate biological and biogeochemical effects of increased ultraviolet radiation on marine ecosystems. ORNL-led studies within the program framework include assays for DNA damage in phytoplankton that can be attributed directly to ultraviolet B radiation as well as changes in biogeochemical cycling as traced using radioisotopic tracers and stable isotopes. The program takes advantage of the complementary and unique skills of each organization involved. This research is important for developing predictive capabilities to assess (over large spatial and temporal scales) the net movement and biogeochemical fate of substances associated with energy development and waste disposal activities, for determining the potential effects of these substances on terrestrial and marine ecosystems, and for evaluating rates of transfer and cycling of carbon between various reservoirs that may be influenced by global change. In addition to DOE's Office of Health and Environmental Research (OHER), the National Science Foundation and the Office of Naval Research support our ocean programs.

Ecosystem Function and Response • Research in ORNL's Environmental Sciences Division for OHER focuses on the Program for Ecosystem Research (PER). This program provides fundamental insights into how ecosystems and organisms respond to environmental variations and changes, how these responses are controlled, and how they can be integrated across organizational levels. PER studies will determine the fundamental processes and properties of ecosystems that are critical to the prediction of ecosystem adjustments to perturbations such as global climate change.

The Walker Branch Watershed is a central research facility for the PER, with ongoing investigations of watershed-scale biogeochemical cycling, atmospheric deposition inputs, atmosphere/canopy interactions, biogenic emission and trace gas flux measurements, mechanisms of physiological response of vegetation to stress, nutrient cycling, subsurface hydrologic transport, and effects of nutrient cycling processes in streams. The goals of the

Walker Branch Watershed Project directly address the objective of the PER by providing a mechanistic understanding of the key processes that regulate ecosystem adjustment.

Results of these process studies provide input to watershed-scale models of ecosystem response and also stimulate new hypotheses of system response that are amenable to testing. Developing a fundamental understanding of the spatial and temporal variations in processes that regulate the storage, transformation, and transport of critical ecosystem components such as carbon, nitrogen, and phosphorus is a key objective of this work. Work is progressing on a major experiment to investigate ecosystem response to long-term shifts in the moisture balance of this deciduous forest watershed. Results of this experiment will significantly expand knowledge of the effects of drought induced by climate change on critical ecosystem processes related to growth, nutrient cycling, and species competition. Other initiatives anticipated in support of the PER include studies of climate warming effects on critical belowground processes, soil carbon turnover, and implications of warming on the processes regulating forest succession.

National Environmental Research Park • The Oak Ridge National Environmental Research Park is directed to include networking with five other DOE parks through the ParkNet System. Park goals focus on

- integration and synthesis of existing data across parks, including site characterization data collected as part of the Environmental Restoration Program;
- coordination of activities among parks;
- on-site data management and data organization (including establishment of computer databases of historical data) and coordination with the Oak Ridge Environmental Information System (see Sect. 5.1.6.2) and DOE waste management activities;
- activities promoting the parks as a coordinated network of cooperating research sites; and
- providing an extant array of experimental sites, the extensive background data, and mechanistic understanding that provide an ecological baseline against which to evaluate ecosystem adjustment to changing environmental conditions.

The park is a component of the Southern Appalachian Man and Biosphere Reserve. Park activity provides regional leadership on biodiversity, climate change, and environmental education. The FY 1993 DOE budget for the park was $128,000; this supported an individual to respond to ParkNet inquiries, to sponsor remote imagery workshops, to organize files on existing environmental data, to travel to Research Park meetings, and administratively to manage and monitor activities on the 5008-ha site. Visitors conducted thousands of user days of environmental research, monitoring, and restoration activities in the park during FY 1993. Alternative sources of funding are being developed to actuate a central plan consistent with Research Park objectives. Issues under consideration include climate change, environmental restoration, environmental risk, and sustainable ecosystems. Activities conducted at but not funded by the park include administration of wildlife management (deer hunts, turkey and osprey restoration, and pest management), wetlands surveys, herbarium development, and rare plant surveys and management. More process-oriented research funded by DOE, the Electric Power Research Institute, and the National Science Foundation has addressed nutrient dynamics and ion chemistry studies on the Walker Branch Watershed, evaluations of stream biological diversity, summer research projects conducted by high school students, studies of greenhouse gas effects on tree growth, and workshops on data sharing with the other biosphere components of the Southern Appalachian Man and Biosphere Reserve. Other studies have evaluated forest fragmentation and recovery, forest responses to drought, stream fauna population dynamics, and effects of geomorphology on potential contaminant

subsurface transport. Test wells are monitored throughout the site. In addition, various forms of remote imagery have been integrated with ground data using geographic information system (GIS) technology for portions of the park.

Future activities and responsibilities of the Oak Ridge National Environmental Research Park are being designed to support DOE's intent to implement an "Ecosystem-Based Management Plan." Such activities are essential to the Department's ecosystem-based management initiatives, which address the ecological concerns of management via the network of parks. ORNL will continue planning for the ecosystem-based management, using the research park as the centerpiece for ecological input. As an example, the Oak Ridge park will serve as a test site for development of a risk assessment framework for management of DOE and Department of Defense lands, supported by a five-year project beginning in FY 1994 and funded by the Strategic Environmental Research and Development Program (SERDP). Two workshops will be held with National Environmental Research Park participants from other laboratories to help develop and test the risk-based management approach.

Theoretical Ecology • Research on integrated assessment will focus on global change and other DOE needs and the theory to integrate biological processes (e.g., biodiversity and structural organization of ecosystems) across different scales. The development of spatially explicit decision models for land management funded by SERDP will be used to assess the impact of DOE activities on natural and cultural resources. The research will build on and require further development of ORNL's expertise in the theory of risk assessment, spatial analysis, and dealing with information at different spatial and temporal scales. Theoretical approaches that are being explored will extend the results of experimental studies being performed as part of the PER to broader spatial and temporal scales and to a wider variety of conditions. See Sect. 5.1.6.4 for a description of ORNL's cross-cutting program in integrated assessment.

Initiative

Subsurface Science Research

We plan to continue our work in hydrology, geochemistry, modeling, and colloid chemistry in support of DOE programs in site-directed subsurface transport of hazardous substances and subsurface microbiology. We will also continue to increase efforts related to heterogeneity of the geological, hydrological, and microbial components of the subsurface environment and will initiate efforts related to the origin or transport of microbes in the deep subsurface. Research in subsurface sciences is directed toward defining, understanding, and predicting the movement of energy-related contaminants in humid regions with highly organic natural waters. This work, which is directly connected to DOE's environmental quality goals and to the characterization and eventual cleanup of contaminated facilities, is expected to grow because it will represent an essential element in the waste R&D plans.

Activities at ORNL consist of laboratory and field studies that are integrated with the development and application of hydrologic and chemical transport models. These studies involve research on the role of colloids and microbial populations in affecting subsurface transformation of byproducts (including mixed wastes), modeling of the spatial heterogeneity of soils, and research on the thermodynamic and kinetic parameters important to contaminant migration at DOE sites. These studies,

as well as new initiatives that are responsive to DOE's waste R&D plans, will continue and will provide a unique and sound foundation for understanding the migration of subsurface contaminants in a humid environment. Funding projections are shown in Table 5.7.

Table 5.7
Budget projections by fiscal year for the Subsurface Science Research Initiative
($ in millions—BA)[a]

	1995	1996	1997	1998	1999
Operating expense	1.7	2.5	2.7	3.0	3.3
Capital equipment	1.0	1.0	1.0	1.0	1.0

[a]Funding is being sought from the Office of Energy Research through the Biological and Environmental Research Program (KP). Not included are additional funds related to this initiative that are anticipated from the Office of Basic Energy Sciences and the Assistant Secretary for Environmental Management.

Waste R&D—Basic Science • Some of DOE's contaminated sites can be cleaned up with existing technologies, but in many cases a better understanding of the complex systems associated with the remediation of past disposal sites and the transport behavior of contaminants is required. Future needs must be identified, and a relatively long-term commitment to research directed at basic science issues related to environmental restoration must be made; goals of this effort are laid out in terms of several decades rather than a few years. Our aim is to integrate multidisciplinary science into a focused program of developing the fundamental knowledge required to allow DOE's restoration efforts to succeed in a cost-effective and environmentally safe fashion. Basic R&D support today will help ensure timely, cost-effective methodologies for tomorrow.

The basic R&D challenge is to address the following broad objectives, which are interrelated and of significant priority in the following order:

- implementing a consistent approach in assessing (1) the impact of remediation on human and environmental health and (2) the health and environmental risks associated with historical, current, and planned disposal operations;
- gaining an understanding of the biological, physical, and chemical factors that control the movement and chemical transformations of radioactive, hazardous, and mixed wastes in subsurface and surface water systems;
- developing methods for the accurate prediction of contaminant movement in the environment;
- developing new remediation technologies (physical, chemical, and biological) for environmental restoration; and
- using methodologies in performance assessments and postremediation monitoring.

These broad objectives demand a variety of technical disciplines and a highly interactive operational structure. For example, significant emphasis must be placed on developing analysis capabilities, including those related to geochemistry and hydrology as well as to risk analysis, and fundamental databases to support the analytical models. The relationships between wastes of different types and a variety of natural processes must be studied. We emphasize microbial transformations that can be used in remediation and other biological parameters that can effectively serve as indicators for risk and performance assessment. This

work will require enhanced computational capability and the use of artificial intelligence and expert systems as means for aiding restoration decisions. Basic research issues of importance to the waste R&D effort will change as technologies develop and as new problems are encountered.

Health Effects and General Life Sciences—KP03, KP04 • Common themes within these activities are interactions of animals, cells, and molecules with their environments. In the analytical technology area, the physical properties of materials of biological or environmental importance, mechanisms that govern transport and chemical transformations of pollutants, and the details of direct interactions of harmful agents with biological materials are studied both theoretically and experimentally. Efforts encompass interactions at the atomic, molecular, and macroscopic levels in solids, liquids, and gases; on surfaces; and at solid-liquid interfaces. Special emphasis is given to interactions in liquids; efforts include Monte Carlo modeling of the effects of radiation on biological molecules in irradiated matter. Strong emphasis is also placed on developing techniques that provide advanced instrumentation for characterizing and sensitively detecting a wide range of chemical species and related biomarkers of health effects. Included in this effort are unique applications of laser optical techniques, ultraviolet and soft X-ray spectroscopic techniques, electron-beam microlithography, electron microscopy, scanning tunneling microscopy, mass spectrometry, and picosecond laser techniques. ORNL's program for experimental studies of picosecond processes in liquids, gases, and molecular clusters concentrates on studies of structure and dynamics relevant to energy deposition. Programmatic areas of emphasis in health and general life sciences also include mammalian genetics, protein engineering, and molecular and cellular biology.

ORNL continues to support OHER's Radon Research Program with the publication of an international newsletter, *Radon Research Notes*. This newsletter describes radon research conducted by DOE, other federal agencies, and the Commission of the European Communities.

Mammalian Genetics • A large mouse colony and staff expertise in genetics, molecular biology, cytogenetics, pathology, reproduction, and development provide the resources for coordinated studies that use mutations of all kinds to investigate genome structure/function correlations, mechanisms of mutagenesis, and the action of genes in development. Hundreds of mutations induced by radiation and chemicals include valuable complexes of overlapping deletions and other rearrangements. In addition, insertional mutagenesis (by transgenic mouse technology) provides molecular tags for access to and cloning of genes, and targeted mutagenesis (by embryonic stem-cell technology) enhances the means for exploring gene function.

Molecular and advanced cytogenetic techniques are used for analyzing the nature of agent-induced and insertional mutations, advancing the understanding of mechanisms of mutagenesis. In addition, the program is a national resource for studying genetic risk from environmental mutagens and for determining the sensitivities and biological properties of diverse types of reproductive cells.

The mouse genetics colony, which propagates stocks of hundreds of mutants that have arisen over decades of mutagenesis studies, is an international resource that is being exploited both through outreach and in-house research and is becoming increasingly important for attempts to understand gene function. Over the past four years alone, mutant stocks have been supplied to over 75 laboratories throughout the world for collaborative or independent investigations. Furthermore, the numerous mutations centered on each of seven

specific loci have been characterized into deletion complexes that constitute invaluable resources for intensive regional genome mapping.

The mouse genome is analyzed with the objectives of building bridges to the human genome and especially of finding functions for human genes that might otherwise be characterized only at the structural level. Through the use of recently developed methods for long-range physical mapping and cloning, detailed maps of selected regions of mouse-human homology are being developed, and the comparative maps are being refined by assigning human cDNA clones to positions on mouse chromosomes. Because neither mutation induction nor certain developmental studies are feasible in humans, the mouse provides an excellent model for exploring the in vivo functions of human genes. The pathology and developmental physiology of selected mouse mutants that provide models for human genetic disorders are investigated in depth. Recent examples are DNA-structure/function studies in stocks propagating mutations that cause congenital cleft palate, polycystic kidney disease, and an autoimmune disorder.

Closely aligned with mammalian studies, work in molecular genetics will include investigations of genomic structure, regulation of gene expression, and structure and function of gene products. Researchers at ORNL can visualize higher order chromatin structure and the three-dimensional structure of nucleosomes (the core particle of chromatin) by using X-ray and neutron diffractometry and special techniques in electron microscope tomography developed at ORNL. Cloning of segments of the eukaryotic genome and their subsequent sequencing are providing new insights about the nature of regulatory elements of DNA and the propensity of small regions of DNA to undergo spontaneous mutations.

Protein Engineering • Protein engineering (site-directed mutagenesis) represents the use of recombinant DNA technology to alter the structure of proteins systematically by replacement, addition, or deletion of amino acids in targeted regions. Since its recent inception, protein engineering has emerged as the most powerful tool for probing relationships between structure and function and has opened exciting new vistas for optimizing properties of proteins for medical, industrial, and agricultural applications.

In its breadth and integration of many activities in molecular genetics and biochemistry, ORNL's program in protein engineering is unique among DOE laboratories. Long-term efforts are focused on enzymes that are relevant to biomass yields and on polypeptide hormones that regulate cellular growth and differentiation. Examples of the former are ribulose bisphosphate carboxylase/oxygenase (Rubisco), which catalyzes photosynthetic CO_2 fixation; phosphoribulokinase (PRK), which catalyzes the formation of the CO_2 acceptor molecule; and thioredoxin (Td), a redox protein that modulates the in vivo activity of numerous enzymes. With respect to Rubisco, two compelling reasons exist for carrying out site-directed mutagenesis: (1) despite the absolute dependence (direct for plant and indirect for animals) of all higher life forms of the enzyme, many mechanistic questions remain unanswered; and (2) if the enzyme's oxygenase activity (detrimental to net CO_2 fixation) could be reduced, major increases in plant productivity might be achieved. PRK is of particular interest because of its ill-understood regulation by photon flux as mediated by Td. The pathway for sulfhydryl-disulfide exchange between Td and target enzymes, as well as specificity determinants of redox proteins, are under investigation.

Examples of the work on polypeptide hormones are human epidermal growth factor (EGF) and its specific cell-surface receptor, which when complexed with EGF mediates regulation of gene expression. Several extracellular protein factors can stimulate the growth of cells and the expression of specific genes believed to be involved in the entrance of

mammalian cells into, and their progression through, the cell cycle. One of the most highly studied of these is EGF, a 6-kDa polypeptide mitogen that initiates its action through high-affinity ligand binding to the specific cell-surface EGF receptor. In response to EGF, the receptor undergoes autophosphorylation on tyrosine residues by its intrinsic protein kinase activity, besides tyrosine phosphorylation of a variety of endogenous protein substrates. This then triggers a cascade of biochemical events, including increased glycolysis and protein synthesis and increased transcription of specific genes, ultimately leading to stimulation of DNA replication and cell division. Some aspects of the function of EGF have been addressed by site-directed mutagenesis of the human gene that was synthesized and cloned in the bacterium *Escherichia coli*.

Recent accomplishments illustrate the diverse scope of the protein engineering program:

- By use of appropriate site-directed mutants, the primary nucleophile of Td was identified.
- A new chromatographic assay was designed for the oxygenase activity of Rubisco; it is more sensitive and convenient than methods described previously.
- By novel combination of chemical modification and protein engineering, the exquisite sensitivity of the CO_2/O_2 partitioning ratio of Rubisco to the length of the aminoalkyl side chain of an active-site lysyl residue was demonstrated.
- By combining site-directed molecular mutagenesis, chemical modification, and nuclear magnetic resonance spectroscopy, the amino acids in EGF essential for binding to the receptor were defined.
- Biological activity of EGF, almost totally eliminated by site-directed mutagenesis of a key residue, could be wholly restored by chemical modification.

Given the relevance of protein engineering to multiple missions of DOE and the proven track record of this program, expansion would be warranted if permitted by budgets.

Molecular and Cellular Biology • Several projects, designed to elucidate molecular aspects of structure and function that are involved in key cellular processes, also serve to support or interface with the other programs described here.

Analyses of satellite DNA sequences and their organization and function in the eukaryotic genome are being studied at different stages of development. Structure/function studies of mammalian chromatin serve to elucidate the functionality of chromosomal elements during cellular development. Molecular details of eukaryotic messenger RNA (mRNA) turnover and its orchestration by key enzymes are being unraveled. Structural biology includes crystallographic analyses of the nucleosome core particle and growth factors.

Research in molecular immunology emphasizes the role of cell-surface receptors in the development of carcinomas and the diagnosis and possible treatment of carcinomas by antibody-directed cell targeting. Initiation events that convert normal cells to potential cancer cells are often mediated by host factors. Ongoing studies of such factors influencing either progression of an initiated cell to a tumor or suppression of its cancer potential are therefore central to the understanding of carcinogenesis in general and radiation-induced cancer in particular.

Recent noteworthy achievements include the following:

- Demonstration that the hydrolysis of mRNA from the 5′ terminus by enzyme(s) discovered at ORNL represents the major pathway for mRNA turnover in eukaryotes.
- Crystallization of reconstituted nucleosomes and preliminary collection of diffraction data to 3 Å.

- Provision of monoclonal antibodies to target cells and receptors to over 200 laboratories worldwide; the demand is rising.
- In the radon program, a recent finding indicating that alpha particles, although lethal to cells they penetrate, can only transform precancerous cells in conjunction with beta and gamma radiation.
- Efficient cryobiological preservation of *Drosophila* (fruit fly) embryos. Cryopreservation of cells and embryos (with the long-term goal of cryopreservation of multicellular organs) has already been applied to issues as diverse as human fertility disorders and livestock breeding. Expansion of medical applications depends on the continuing elucidation of the basic mechanisms in cell freezing; such studies continue. An important recent advance has been the successful cryopreservation of *Drosophila* embryos with ~50,000 cells, the most complex tissue to be recovered intact. This research, which was funded in part by the National Science Foundation, won a 1993 R&D 100 award.

Initiative

ORNL Genome Program

ORNL is strongly committed to the national effort to analyze the human genome. Comparisons of structure and function within related regions of the mouse and human genomes and development of advanced sequencing and mapping techniques are two thrusts of the ORNL program.

Because of the extensive homologies that exist between the genomes of humans and mice, because the mouse genome can be altered by experimental means, and because developmental and other experimental studies that are not feasible in humans can be done in mice, the mouse provides an excellent modeling for exploring the in vivo functions of human genes. Mutations generated in mice provide powerful tools for the correlation of genome structure with function and will prove crucial in deciphering biological information containing in emerging human physical maps.

DOE's Office of Health and Environmental Research has funded a multiple-investigator project on mouse-human genome relationships that is proceeding as follows.

- Using long-range physical mapping and cloning, develop detailed maps of selected regions of mouse-human homology, including proximal mouse chromosome 7 (Mmu7) and related regions of human chromosome 19q HSA19q, in collaboration with the Human Genome Center at Lawrence Livermore National Laboratory.
- Refine and expand the existing mouse-human comparative genetic map by assigning conserved human DNA markers, especially cDNA clones, derived from HSA19 and other targeted human regions to specific mouse chromosomes.
- By means of our capability in targeted mutagenesis, determine the function of some of the mapped human cDNAs.
- Pursue intensive structure-function studies in genomic regions for which deletion complexes have been generated.
- Study the feasibility of inducing deletion complexes at specifically targeted sites throughout the genome, using rapid, cost-efficient ES-cell-based methods.
- Create molecularly tagged mutations throughout the mouse genome by insertional mutagenesis, using both pronuclear injection and embryonic stem-cell techniques.

- Use mutagenesis techniques to create models of human genetic disorders.
- Establish a national database for transgenic mouse mutants.
- Employ artificial intelligence and neural network techniques to identify important DNA sequence patterns.

New methods to increase the rate and accuracy of DNA sequencing and mapping are being developed at ORNL for analysis of mammalian genomes. These efforts include

- development of mass spectrometric methods for rapid analysis of DNA sequencing products;
- use of solid-state oligonucleotide arrays to analyze target DNA sequences by hybridization;
- application of scanning-probe microscopy to high-resolution physical mapping of DNA molecules;
- development of new DNA labels containing nonradioactive metal isotopes for detection by luminescence, mass spectrometry or electrochemical techniques;
- development of sensitive optical techniques for quantitative detection of unlabeled DNA in hybridization arrays; and
- fabrication of devices for microscale purification and sequencing of DNA.

Unique computer-based sequence analysis methods for identification of biologically important regions in newly sequenced DNA are being developed, drawing on neural network, artificial intelligence, and parallel computational techniques. ORNL's Gene Recognition and Analysis Internet Link (GRAIL) rapidly and reliably locates gene components such as exons, introns, and gene control elements. Related software is used for the automated assembly of these components to describe whole genes. In addition to GRAIL's use in the mouse genome program, several hundred other laboratories access it via the Internet for analysis of important human disease genes.

The Human Genome Management Information System at ORNL (discussed in Sect. 5.1.6.2) provides the DOE and National Institutes of Health (NIH) human genome programs with a communication network throughout the international community that is engaged in human genome research. The *Human Genome News* and the *DOE Human Genome Program Report* are published at regular intervals by this activity. The *Human Genome News* is also available to a large user community via the Internet.

Resources that support the ORNL Genome Program, at ORNL and in the local area, include

- a 250,000-mouse colony organized for genetic studies;
- a transgenic mouse facility;
- a collection of several hundred stocks of mouse mutations, propagated by breeding or preserved as frozen embryos;
- an NIH-supported database for transgenic mice;
- a program in targeted mutagenesis by embryonic stem-cell technology;
- the ORNL Center for Computational Sciences;
- synthetic chemistry laboratories;
- laboratories for high-resolution mass spectrometry and resonance ionization spectrometry ;
- a nucleic acids chemistry laboratory with oligonucleotide array synthesis capability;
- analytical chemistry facilities that include high-resolution Fourier transform (FT) mass spectrometry, FT nuclear magnetic resonance, FT infrared, and ultrasensitive laser luminescence capability;
- facilities for sensitive detection of labeled DNA fragments by mass spectrometry; and
- facilities for sensitive detection by enhanced Raman, luminescence, and phosphorescence.

Construction of the Center for Biological Sciences, described in Sect. 4.2, would extend and enhance these resources.

ORNL divisions interacting to develop this multifaceted program include Biology, Chemical and Analytical Sciences, Engineering Physics and Mathematics, Health Sciences Research, and Instrumentation and Controls. Table 5.8 lists the budget projections for this initiative.

Table 5.8
Budget projections by fiscal year for the ORNL Genome Program
($ in millions—BA)[a]

	1995	1996	1997	1998	1999	2000
Operating expense	6.8	7.1	7.4	7.7	8.0	8.3

[a]Funding is being sought from the Office of Energy Research through the Biological and Environmental Research Program (KP).

Carbon Dioxide Research—KP05 • ORNL is a center of expertise in developing global biogeochemical models, implementing data and information systems, fostering the application of high-performance computing to atmospheric general circulation models (GCMs), conducting field and laboratory research on the effects of CO_2 on vegetation, and developing unique instrumentation packages for global applications. These activities are the foundation for the ORNL Center for Global Environmental Studies, which involves staff members from many ORNL divisions as well as outside collaborators.

Global Carbon Cycle • The main objective of the Global Carbon Cycle Research Program is to develop a scientific basis for predicting changes in atmospheric CO_2 concentrations in response to continued releases of CO_2 by combustion of fossil fuel. Future activities will encompass more research focusing on terrestrial and oceanic carbon dynamics, global carbon cycle modeling, and the potential for positive feedback to dramatically alter our current understanding of the carbon cycle. Research will concentrate on multidimensional models of the global carbon cycle; this will yield various estimates of atmospheric CO_2 when given different levels of fossil fuel use and other variables relating to biogeochemical dynamics. The research must be integrated with the work of other collaborators to develop the information and models needed to provide accurate projections of CO_2 buildup in the atmosphere (from both natural and human sources) during the next century.

ORNL recognizes the importance of understanding critical terrestrial carbon cycle processes and has been devoting efforts to unraveling these complex and interrelated issues of carbon flux for the last few years. As the DOE Office of Health and Environmental Research moves toward the Terrestrial Carbon Program with the announcement of opportunities for laboratories in fall 1994, ORNL intends to pursue studies of terrestrial carbon dynamics that complement existing field studies and global carbon cycle model development.

Carbon Dioxide Information Analysis Center • The Carbon Dioxide Information Analysis Center (CDIAC) compiles, evaluates, and distributes information on CO_2, other greenhouse gases, and long-term climate changes, in support of the CO_2 research program. In the coming years, the center's research activities will reflect the new directions of the program and will include research in all aspects of the global climate change issue. CDIAC also houses the World Data Center–A for Atmospheric Trace Gases. See Sect. 5.1.6.2 for additional information.

Computer Hardware, Advanced Mathematics, and Model Physics • The Computer Hardware, Advanced Mathematics, and Model Physics (CHAMMP) Program is directed toward the development of an advanced climate model that uses the hardware and software capabilities of massively parallel processing (MPP) computers and incorporates the best numerical approaches for atmospheric and oceanic dynamics, combined with the most accurate representation of cloud feedbacks, chemical processes, and terrestrial systems. In the near term, CHAMMP will achieve improved GCM performance by using MPP supercomputers such as those in the ORNL Center for Computational Sciences (CCS). ORNL scientists are working with staff members from Argonne National Laboratory and the National Center for Atmospheric Research to provide parallel implementations of the Community Climate Model and to improve key numerical algorithms for parallel computation. ORNL scientists are keenly interested in CHAMMP projects that will couple atmospheric, oceanic, and terrestrial models. With these models, new understanding of the CO_2 problem may be gained.

Carbon Dioxide Effects • Research at ORNL in support of the DOE Direct Effects Program has shown that the most important effects of increased concentrations of CO_2 in the atmosphere on forest tree species may be the secondary influences on resource use and stress resistance. Following on this principle, researchers are investigating the potential for elevated concentrations of atmospheric CO_2 to ameliorate the adverse effects of climate warming on forest tree species. Tree seedlings are being grown in a novel experimental system consisting of multiple temperature-controlled, open-top chambers in the Oak Ridge National Environmental Research Park. Physiological and whole-system responses will be measured to explore the mechanisms of plant and ecosystem adjustment. This research will lead to a more realistic assessment of the integrated responses of terrestrial ecosystems to global change. Experiments now under way are investigating the role of CO_2-temperature interactions on the growth of forest tree species.

Atmospheric Radiation Measurement • The Atmospheric Radiation Measurement (ARM) Program is a DOE initiative to aggressively monitor atmospheric phenomena that affect heat flux, with the objective of providing an experimental testbed for studying the effects of atmospheric phenomena, particularly cloud interactions, on long-wave radiative processes. This information will be used to improve the modeling of atmospheric and radiative process, with the ultimate goal of improving GCMs. ORNL serves as the data center for all data generated by this program. Staff in the ORNL Environmental Sciences Division are developing the ARM archive facility to provide scientific data management for the project data, with support from the CCS. Also under development are methods to document and summarize the data and to provide user access tools. Documenting and summarizing the ARM data will be particularly critical because the ARM archive will be the primary point of contact for the general scientific community seeking data from the project. The ARM archive activity is described in more detail in Sect. 5.1.6.2.

Center for Global Environmental Studies • The exploration of global environmental issues is of critical importance in determining directions for the future. These issues are complex, interwoven, and global in scale; they include greenhouse gases, climate change, ozone breakdown, deforestation and desertification, resource depletion, and the spread of pollution. The ORNL Center for Global Environmental Studies (CGES) provides an interdisciplinary base for exploring these issues. The center draws on the Laboratory's unique capabilities in working toward three main goals:

- improving the understanding of the global-scale workings of environments in air, on land, and in water;
- developing capabilities for anticipating the long-term, large-scale effects of human actions on the biosphere; and
- identifying appropriate options for technological and societal responses.

Our approach to these global issues includes a large-scale, long-term view; a commitment to collaboration among institutions and among disciplines; and a continual emphasis on realistic policy.

The unifying framework of these efforts is global systems analysis: the development of increasingly sophisticated models reflecting the dynamic interactions of subsystems (e.g., global vegetation, human cultures and behaviors) and earth systems (e.g., atmospheric chemistry, ocean composition and circulation) and the links between air, land, and sea. The long-term goal is to develop models that include the effects of demographics, land-use patterns, economics, ecological relationships, and other factors influencing the environment.

Four areas of concentration complement this central focus:

- Measurement science and instrumentation. ORNL expertise in instrumentation is being directed toward atmospheric, terrestrial, and aquatic research. Capabilities include laser-based instrumentation; mass spectrometry and isotopic analysis; remote sensing and fiber optics; and automation, miniaturization, and portability. Logical applications of this expertise include laser-based devices to measure trace gases, temperature, and pressure; low-cost, air-dropped packages for reading atmospheric or ocean conditions; and instruments for studying cloud formation and atmospheric properties in support of the ARM Program.
- Data systems for handling the very large amounts of data collected in the course of global environmental research, presenting the data in a user-friendly form, and ensuring the long-term usability of information.
- Large-scale environmental studies. Because global-scale studies must examine the environment from a longer perspective than that of traditional ecological research, the CGES is developing tools and techniques for understanding how to conduct research on a global scale.
- Policy, energy, and human systems analysis. The effects of human activity and policy must be incorporated into global environmental studies. Anthropologists, climatologists, ecologists, economists, geographers, planners, political scientists, and sociologists are needed to examine the decision processes involved in global management of risks and resources. We are developing a practical approach to the problems of decision making involving many players and complex technical issues. The policy issue work of the CGES is supported through DOE's Assistant Secretary for Policy, Planning and Program Analysis and is coordinated by that office (see Sect. 5.1.5.1).

Current research areas include the following.

- Development of integrated land-use models. Studies of tropical deforestation in Brazil, sub-Saharan Africa, and Southeast Asia are contributing to the development of models that integrate the socioeconomic and biophysical aspects of land use. This work involves close collaboration among experts in geography, ecology, transportation, economics, and other disciplines.
- Refined modeling of the global carbon cycle. Carbon dioxide is the greatest single contributor to the greenhouse effect; therefore, a clearer picture of the global sources, sinks, and fluxes of carbon is essential in understanding the greenhouse effect and the climate

changes it may bring. Rigorous use of models developed and applied by ORNL's Global Carbon Cycle Research Program has led to the current development of new models that reflect various feedbacks within the carbon cycle. These new models are contributing to the development of fully integrated carbon cycle models.

- Information analysis centers. Databases on worldwide climate will be useful in determining whether global warming has actually occurred. The ARM user facility and data archive and the Carbon Dioxide Information Analysis Center provide a sound basis for these efforts. Development of other areas (e.g., biomass data and human systems data) is proposed, as is development of visualization systems for data-intensive studies. We are also collaborating in an initiative to establish a Center for Human Dimensions and Global Change Data.
- International development and global environment. The impacts of both climate change and climate-change policies will fall heavily on developing countries. We are identifying vulnerable regions, determining the effects of existing aid programs on global environmental change, analyzing the impacts of change on current development plans, and finding new opportunities to enhance development while pursuing environmental goals. Energy efficiency, institution building, and technology transfer for developing countries are high priorities for this activity.
- Improved radiation measurement instruments for the ARM program. We are developing advanced instrumentation that will provide better data on global radiation and heat fluxes. This will allow development of more accurate atmospheric models.
- Ultraviolet B (UV-B) research. Much ozone depletion is due to various energy technologies, and other adverse effects of pollutants derived from fossil fuel may be amplified by ultraviolet light. A comprehensive analysis of the technical issues associated with UV-B radiation should help to resolve many of the uncertainties dealing with measurement sciences and instrumentation needs and will bring a focus to the issues surrounding UV-B measurements and the effects of potential UV-B increases on biological systems.
- Integrated assessments. Existing approaches to analyzing the impacts of global environmental change are generally restricted to projecting short-term changes in resources (e.g., surface water on coastlines) onto current socioeconomic and geographical conditions. We are working to provide an interdisciplinary analysis, whose starting point will be the real-world problems that policy makers face in a given region and time; the analysis will allow for technological and demographic changes and will indicate how climate change would affect decisions. Our long-term aim is to devise personal computer–based decision support systems for federal, state, and local decision makers.
- A global vegetation model. Building on our current study of the global carbon cycle, we plan to extend the vegetation model to the entire world. The expanded effort (estimated to take 10 to 20 years) will represent a major contribution to global modeling.
- Development of improved data storage and access techniques. New ways of archiving and accessing information are needed to cope with the data acquired by the ARM project and other data-intensive programs. Our strengths in information analysis and management, combined with ORNL's growing expertise in scientific computing, give us a solid basis for developing better data storage systems and techniques.
- Predictive models for water resources. We are using large-scale assessment techniques and tools developed for assessment of global effects on other resources to develop a major new initiative in water resources directed toward the needs of developing countries.

We will develop predictive models that will help decision makers understand freshwater ecology, hydrology, and water resource management in the context of global change.

The CGES draws on proven expertise and worldwide scientific connections while laying the foundation for expanded, focused research into the problems of global change. The center is uniquely positioned to serve the needs of federal agencies and international efforts and to make a significant contribution to our understanding of the biosphere. Table 5.9 lists budget projections.

Table 5.9
Budget projections by fiscal year for the Center for Global Environmental Studies[a,b]
($ in millions—BA)

	1995	1996	1997	1998	1999	2000
Operating expense	21.0	21.0	21.0	21.0	21.0	21.0
Capital equipment	1.0	0.5	0.5	0.5	0.5	0.5

[a]These projections include university subcontracts. About 80% of funding would come from DOE; the remaining 20% would be non-DOE funding.

[b]Funding is being sought from the Office of Energy Research through the Biological and Environmental Research Program (KP).

Medical Applications—KP06

Nuclear Medicine • The ORNL Nuclear Medicine Program focuses on the design and development of new tissue-specific radiopharmaceuticals for diagnostic and therapeutic applications in nuclear medicine. Key strengths of the program are radiopharmaceutical chemistry, radiochemistry, development of radioisotope processing techniques, and radionuclide generator research. The High Flux Isotope Reactor represents an important resource for this program, and the development of radionuclide processing technology and generator research are major areas of productive research.

A key example is the development of the $^{188}W/^{188}Re$ generator system, which provides carrier-free ^{188}Re as either perrhenate or perrhenic acid for radiolabeling various therapeutic agents. Large-scale prototypes of the $^{188}W/^{188}Re$ generator have been developed, and a clinical model was patented in FY 1993. The system has recently been licensed to Isotope Product Laboratories, Inc., Burbank, California. Optimization of the reactor preparation and processing of a variety of other radioisotopes of biomedical interest is also in progress.

Another area of current research is the development of ^{123}I- and ^{18}F-labeled cerebral receptor antagonists to measure changes in neurotransmission encountered in many neurological diseases. The goal is to measure, by means of external imaging techniques, changes in receptor density or activity that occur in many diseases. Agents under development include improved analogs that bind to the cholinergic-muscarinic receptors involved in dementias such as Alzheimer's disease and new analogs that bind to the serotonergic receptors that are involved in mood disorders. In conjunction with the syntheses of these and other agents, new and improved radiolabeling techniques are being developed for radio-iodination of molecules sensitive to the usual methods.

Improved agents to evaluate pancreatic insufficiency are also being developed, and an ^{131}I-labeled triglyceride test agent is being used in the evaluation of gastrointestinal disorders involving pancreatic disease by means of a simple urine test. Clinical trials with this agent

are under way at the Clinic for Nuclear Medicine at the University of Bonn, Germany. A variety of other agents are being evaluated in both preclinical and clinical collaborations, including clinical studies with ^{188}Re-labeled antibodies for cancer therapy.

More than 20 medical cooperative programs at university hospitals and research institutions in the United States and abroad represent an effective mechanism for further evaluation of agents developed in this program through collaboration with programs featuring special expertise in cardiology, oncology, and other areas. Research in this program continues to receive international recognition, and a variety of invention disclosures, patents, and licenses have been consummated. The balance between basic R&D at ORNL and interaction with other institutions forms the basis for continued strength of this program.

Molecular Immunology • The proteins on the surface of cells are tissue-specific and may be altered in kind and amount in the carcinogenic process. We have developed monoclonal antibodies that recognize epitopes on a glycoprotein (thrombomodulin) that is expressed exclusively by lung endothelial cells. This apparently unique glycoprotein provides opportunities for the use of monoclonal antibodies for imaging both the vasculature and tumors. Liposomes can be targeted with these monoclonal antibodies, with the possibility of targeting chemotherapeutic agents. Potential applications will be explored in the light of results from basic studies of the surface proteins in normal and cancer cells.

5.1.1.2 • Office of Scientific Education and Technical Information

University and Science Education—KT

The ORNL-obligated portion of the University and Science Education program supports the administration and conduct of both university-level and precollege mathematics and science education activities for precollege, university, graduate, and postgraduate students and faculty. ORNL's education activities are described in Sect. 5.1.6.3.

5.1.1.3 • Office of Laboratory Management

Multiprogram Energy Laboratories Facilities Support—KG

The DOE Multiprogram Energy Laboratories Facilities Support (MEL-FS) program provides funding for general-purpose, line-item construction projects at ORNL. General-purpose facilities relate to many programs and may include offices, laboratories, and shop buildings that house administrative and Laboratory-wide support functions; utility systems; and roads. Line-item construction projects are those with a total estimated cost of $2 million or more.

ORNL has a large backlog of facilities for which a number of corrective construction projects are proposed. Facilities plans are discussed in Sects. 6.3 and 7.2. Table A.3 in the Appendix provides a description of ORNL's facilities needs and a complete list of proposed line-item construction projects, including those that are being submitted to the MEL-FS program.

Laboratory Technology Transfer—KU

The Laboratory Technology Transfer program helps to bridge the gap between R&D and commercialization. This program supports DOE's portion of cooperative R&D agreements (CRADAs), which provide a range of mechanisms for joint R&D efforts between the

national laboratories and industry. ORNL oversight of DOE-ER projects funded through this program is the responsibility of the Science and Technology Partnerships Office (formerly the Office of Guest and User Interactions), which also develops and implements CRADAs at ORNL. Individual CRADAs are discussed in the appropriate programmatic areas in this section. Functions of the Science and Technology Partnerships Office (CRADAs, user agreements, and other cooperative actions between ORNL and external groups or individuals) are described in Sect. 5.1.6.3.

5.1.2 • Energy Programs

5.1.2.1 • Assistant Secretary for Energy Efficiency and Renewable Energy

ORNL works with industry on a wide range of programs for the Assistant Secretary for Energy Efficiency and Renewable Energy (DOE-EE). The Laboratory's goal is the introduction of cost-effective and environmentally acceptable technologies that result in increased efficiency of energy use and increased use of renewable energy, and thus increased national economic security and global competitiveness. To ensure that industry is involved in appropriate projects, the ORNL Energy Efficiency and Renewable Energy Program uses cost-shared subcontracts and cooperative agreements. ORNL is also participating in industry-specific needs assessments in collaboration with DOE Headquarters (DOE-HQ), industry, and other national laboratories, with the objective of matching industry's research and technology needs with available scientific and engineering expertise.

ORNL's overall funding from DOE-EE has increased over the past several years, and this trend is expected to continue. New projects are proposed in Solar Energy (program EB), Industrial Energy Conservation (program ED), and Building Technologies (program EC). The largest increases for continuing programs are in Industrial Energy Conservation and Transportation (program EE), with substantial increases for continuing programs in Solar Energy and Building Technologies.

Electric Energy Systems—AK

ORNL provides field management of three programs for the Office of Energy Management: the Superconductivity Program for Electric Power Systems, Power Transmission and Distribution Technologies, and Electric and Magnetic Field (EMF) Effects. ORNL also provides assistance in engineering and analytical studies and technical support for planning and decision-making.

The goal of the Superconductivity Program for Electric Power Systems is to develop the technology base needed for U.S. industry to proceed to commercial development of electric power applications of high-temperature superconductors. The three major elements of the program are wire development, electric power applications development, and the superconductivity partnership initiative. Superconductivity collaborative agreements are the principal mechanism used to enable industry progress. Completion of the superconductor generator project with General Electric Company is expected in early FY 1996. In a collaborative project with Intermagnetics General Corporation, demonstration of a prototype high-temperature superconducting transformer is scheduled for late FY 1996.

In Power Transmission and Distribution Technologies, ORNL is working with the DOE power marketing agencies, the Electric Power Research Institute, and other interested parties to improve electric system capacity, flexibility, and efficiency while maintaining high

reliability. The program includes development of real-time control to allow power systems to be operated closer to thermal limits; high-capacity options such as high-voltage dc transmission; and technologies designed to improve understanding of transient phenomena and dielectric materials characteristics. Milestones for FY 1996 include demonstration of the feasibility of controlled turn-off, high-voltage dc converters.

In EMF Effects, ORNL is assisting DOE in implementation of the National EMF Research and Communications Program through the development and implementation of engineering and science research plans. Activities include exposure assessment, dosimetry and biophysical modeling, instrumentation development, field characterization, and field management.

Energy Storage Systems—AL

ORNL's program to develop thermal energy storage technologies for industries and buildings, which currently consists of cost-shared subcontracts for development of wallboard with enhanced heat capacity and development of a low-temperature thermal energy storage system for off-peak refrigeration, is to be closed out in FY 1994.

Geothermal Systems—AM

ORNL provides technical and analytical support for evaluating the environmental impacts of geothermal development in the state of Hawaii. The work is expected to continue until FY 1995.

ORNL is also conducting a continuing study on chemical reactions in geothermal systems for the DOE Idaho Operations Office (DOE-ID) and the DOE Geothermal Division and providing support to the California Energy Commission in an assessment of geothermal heat pump performance and economics.

Hydrogen—AR

Building on a recent demonstration of hydrogen production in an evacuated photobiological reactor, ORNL proposes to investigate hydrogen production by photosynthetic water splitting as a renewable source of elemental hydrogen. A photobiological reactor to produce hydrogen in subambient atmospheres will be designed in FY 1995, with measurement of hydrogen production rates by selected algae beginning shortly thereafter and continuing into FY 1996. Discussions are under way on other studies of hydrogen as a replacement for fossil fuels. ORNL also proposes a study to identify engineering requirements for a natural gas–reformer fueling station to produce and distribute hydrogen as an alternative transportation fuel. This research also receives support from the Assistant Secretary for Fossil Energy.

Hydropower—CE

ORNL provides research and other technical assistance to DOE-HQ and DOE-ID on environmental aspects of DOE's Hydropower Program. The second volume of the Environmental Mitigation Study, covering fish passage, was completed in FY 1994. In addition to ongoing research on mitigation practices, work in FY 1994 includes support to DOE's Advanced Hydropower Turbine Initiative and a reconnaissance study of ways to improve

hydropower production at existing facilities. Hydropower funding is expected to remain at about the present level.

Solar Energy—EB

ORNL provides field management for the Biofuels Feedstock Development Program (BFDP), a national program for the development and demonstration of environmentally acceptable, commercially viable biomass supply systems based on energy crops. Areas of emphasis include model wood and herbaceous energy species; environmental research; systems integration and analysis; scale-up, feasibility, and demonstration; and data and information management. Energy species research has emphasized selection, characterization, and improvement through breeding and genetic studies, as well as tolerance to biotic and abiotic stresses.

The BFDP has completed a study co-sponsored by the Tennessee Valley Authority to determine the costs and environmental impacts of producing energy crops in the Tennessee Valley and surrounding region. An integrated analysis will quantify and characterize the potential production of energy crops for an 11-state region across the South and Midwest. Results from regional economic analyses will provide input for new studies examining the impacts of energy crop deployment on regional landscape ecology, water quality, and water balances.

In other solar energy projects, ORNL is investigating strategies to speed the adoption of photovoltaic systems in residential and light commercial buildings; this effort is scheduled for completion in FY 1995. An evaluation of the Regional Biomass Energy Program (RBEP) is to be completed in FY 1994, with additional work proposed in quantification of energy and economic impacts of the RBEP. ORNL also provides U.S. representation to the International Energy Agency's Information Center for the Analysis and Dissemination of Demonstrated Energy Technologies. New projects are proposed in advanced ethanol fuel production processes. ORNL proposes increases in funding for solar energy in future years.

Buildings Sector—EC

ORNL is responsible for field management in four program areas: Building Thermal Envelope Systems and Materials, Building Equipment Technology, Existing Buildings Research, and Buildings Technology Transfer.

One of ORNL's newest national user facilities is the Buildings Technology Center (BTC), an integration of the Roof Research Center with other ORNL buildings research facilities. The BTC is designed to aggressively promote the integration of building technologies and will be the principal resource for an ORNL-sponsored, competitive Building Energy Technology Internship Program for students from minority educational institutions.

Major building envelope research projects include a CRADA with the insulation industry to compare the performance of foam insulation blown with chlorofluorocarbon (CFC) alternatives to that of conventional CFC-blown foams, and a joint project with Dow Corning, Inc., to examine the efficiency of reroofing with spray-foam insulation over an old, wet asphalt roof. Work continues to characterize the thermal performance of loose fill insulation in attics.

The building materials program addresses the development and characterization of new and existing insulation materials for buildings and refrigeration equipment. The goal is to develop new, cost-competitive materials that can reduce building energy consumption by

20% by 2010. Specific tasks are conducted in the areas of advanced materials research, existing materials performance, and retrofit insulation. Special emphasis is placed on development of powder-filled evacuated panels with $R > 50$/in. and a lifetime greater than 30 years.

The goal of the building equipment technology project is to generate new concepts and develop technologies for improving the energy efficiency and load characteristics of energy conversion equipment used in residential and commercial buildings. In FY 1994, a license agreement was signed by Carrier Corporation for the generator-absorber heat exchange (GAX) absorption residential heat pump technology developed under an ORNL subcontract with Phillips Engineering Company. This technology promises heating efficiency at least 50% better than the best current technology and cooling efficiency comparable to electric air conditioning. The GAX residential unit is the first in an absorption system family that DOE and ORNL plan to bring to the market. Other products will serve the light commercial and large-building chiller markets with high cooling efficiency. A CRADA with the Association of Home Appliance Manufacturers (AHAM) has the objective of developing and demonstrating a residential CFC-free refrigerator/freezer that is 50% more efficient than the existing industry standard. AHAM members are scheduled to begin phasing these improvements into their products in 1998. ORNL has also developed and patented a technique that extends the liquid overfeed concept to residential air conditioners and heat pumps.

The existing buildings research program supports public- and private-sector efforts to improve the energy efficiency of existing residential and commercial buildings. In a collaborative project involving the DOE Office of Building Technologies, the DOE Federal Energy Management Program, the U.S. Air Force, and the U.S. Army, ORNL is developing and validating guidelines for incorporating energy efficiency into base housing revitalization. Other projects include examining the cost-effectiveness of replacing central air conditioning systems and duct system sealing in Arizona, developing an advanced single-family audit for low- and middle-income housing, and providing technical support to state weatherization programs.

The purpose of the buildings technology transfer program is to ensure that research results are transferred quickly and effectively to private- and public-sector users. ORNL has joined with the DOE regional energy office, utilities, and other organizations to establish a task force that focuses on buildings programs in the southeastern United States. The program is developing a touch-screen computer audit to help customers in home energy centers determine the correct amount of insulation for their homes.

ORNL anticipates playing a major role in implementation of the Climate Change Action Plan. Proposals have been made for work on efficiency standards for distribution transformers and for assistance to DOE in development of a strategy to speed commercialization of high-efficiency appliances.

Other ORNL efforts in buildings research include a cooperative project with the National Association of Home Builders to identify advanced housing technologies; technical assessments of industrialized housing technologies; technical support to federal infrastructure modernization efforts, technical support to a historically black university in execution of research proposals supportive of the objectives of the Office of Building Technologies; and a study on public participation in the siting of energy efficiency and renewable energy facilities.

Industrial Energy Conservation—ED

ORNL performs applied R&D on four projects for the Advanced Industrial Concepts (AIC) Division. The AIC Materials Project develops new and improved materials and manufacturing technologies for more efficient energy use. High-temperature intermetallic and metallic alloys with high ductility, corrosion resistance, and strength are being developed. Metal-bonded composites are being developed for optimal use at temperatures between those of currently available alloys and ceramics. Coatings and engineered porous materials are being evaluated for various applications. Microwave technology, which offers new and exciting potential for materials with unique properties, is being pursued.

For the AIC Advanced Bioprocessing Concepts Project, fluidized-bed bioreactors are being studied for both three-phase and four-phase operations, including an extraction phase to combine fermentation and separation. Gas-phase bioreactors are also being examined. Predictive models will be developed for ultimate use in scale-up of organic acid production. New initiatives in FY 1995 will address the use of biocatalysts in the presence of organic media and the use of carbon dioxide for the production of fuels and chemicals. The program also supports an annual Symposium on Biotechnology for Fuels and Chemicals. Other AIC projects include research on photobiological reactions for enhanced capture of solar energy and thermal sciences research to investigate concepts such as superconducting thermomagnetic energy conversion.

The continuous fiber ceramic composite (CFCC) program for the Office of Waste Reduction Technologies focuses on development of processing methods for fabrication of CFCC components for industrial applications. CFCCs offer high-temperature stability, corrosion resistance, and light weight. ORNL tasks include technical assistance in project evaluation and industry interaction, and R&D in composite design, materials characterization, test methods development, and performance-related phenomena.

A continuing project on materials for advanced industrial heat exchangers provides materials technology support to DOE and its contractors for heat exchanger development projects. Another continuing project on chemical industrial heat pumps will develop high-lift heat pumps that use industrial reject heat to produce plant utility-grade process heating and cooling. The schedule calls for completion of proof-of-concept experiments in FY 1995, completion of bench-scale development in FY 1996, and field testing of prototype units in FY 1997.

ORNL and the DOE Oak Ridge Operations Office are participating in DOE's Advanced Systems Turbine Initiative by coordinating the materials/manufacturing task, with the goal of developing materials and manufacturing techniques to withstand turbine inlet temperatures greater than 1400°C. A draft program plan to be completed in FY 1994 defines areas for project solicitations to be issued in FY 1995 and FY 1996. An abradable seal coating material will be fabricated and evaluated in FY 1995. A report on long-term creep and stress rupture testing will be completed in FY 1996.

ORNL provides technology development support to the Motor Challenge Program, a major new initiative in the development of energy-efficient motors. Validation and measurement techniques are being developed and a database of existing motors is being compiled. A National Efficiency Assessment will be completed in FY 1995.

Two new waste reduction projects are proposed. A project in cellulosic waste minimization and bioconversion consists of modification of biocatalysts to allow the use of waste-paper in biofuels and chemicals manufacturing processes. Another project will investigate microwave treatment of wood to make the paper pulping process more energy efficient.

Three projects are under way for the Office of Industrial Processes: a demonstration of advanced aluminum forming techniques, to be completed in FY 1994; a new project on separating hydrogen from styrene, widely used in chemicals production, scheduled to be completed in FY 1994; and a project on alternative feedstocks for chemicals and petroleum refining industries, part of a cooperative initiative with four other national laboratories, in which ORNL is responsible for developing advanced technology for bioprocessing and will have an increasing role in thermochemical conversion. An advanced bioreactor system for bioproduction of organic acids is to be selected in FY 1995.

Three new projects involving paper pulping processes are proposed: R&D on a method of separating inked from uninked pulp fibers that could offer significant energy savings in the paper recycling process; use of optimized process chemistry and advanced membrane separations to achieve near-complete recycle of water process streams; and microwave processing combined with genetic/enzyme engineering to optimize the amount and activity of enzymes during the pulping process.

Transportation—EE

The scope of ORNL's work in transportation encompasses materials development, alternative fuels, propulsion technologies, transportation data, and policy analysis.

ORNL has developed the technology base required for reliable ceramics for use in advanced heat engines and is working to reduce the cost of ceramics, with emphasis on near-term applications in conventional engines. Most of the work will be accomplished by the ceramic industry, with technology support from government laboratories and universities. The technology will be developed in close coordination with the ongoing DOE and industry engine development programs. Milestones in the program include demonstration of an order-of-magnitude cost reduction in manufacturing of ceramic engine components and completion of casting trials for low-expansion ceramics for exhaust ports in FY 1995 and completion of the development of ceramic life prediction methodology in FY 1996.

The High Temperature Materials Laboratory (HTML) is a significant resource for this program. The HTML, one of ORNL's national user facilities, houses dedicated laboratories and special instruments to support advanced materials research. An expert staff works with prospective users to define the details of research proposals and then assists the user in conducting the research and in analyzing and interpreting the results. The combination of state-of-the-art instruments and staff expertise is highly effective; user projects span the materials spectrum from superalloys to ceramic composites. At the end of seven years of operation, in July 1994, 215 nonproprietary user agreements (110 industry, 105 university) and 45 proprietary agreements (all industry) were in place. The agreements cover 450 approved research projects in various stages of completion, involving about 550 individual users performing research in the HTML.

Research is conducted in seven user centers in the HTML. One of these, the Ceramic Manufacturability Center, is a partnership between DOE-EE, the Office of Energy Research (DOE-ER), and the Assistant Secretary for Defense Programs. It is described in detail in Sect. 5.1.6.4. Also described in Sect. 5.1.6.4 is a new neutron residual stress facility, a partnership between DOE-EE and DOE-ER, which is scheduled for full operation in early FY 1996.

The HTML Fellowship Program provides educational opportunities for industrial researchers, graduate students, and university faculty members, emphasizing research

conducted in the HTML. In FY 1994, four industrial fellows, two faculty fellows, and six graduate fellows participated in the program.

Alternative Fuels Compatible Materials R&D focuses on resolving problems caused by new fuels in engines and vehicle systems, as well as fuels infrastructure problems. A needs assessment and draft multiyear program plan have been completed. A study of composite cylinders for compressed natural gas is nearly complete, and an engine test cell for a collaborative study with General Motors on improved catalysts has been built. This project will end in FY 1994. In the electrochemical propulsion materials area, a draft multiyear program plan and needs assessment were completed in FY 1993. Lightweight materials development addresses materials and process technology to aid in automobile weight reduction. A multiyear program plan was completed in FY 1993 and work was initiated on adhesive bonding of polymer components. Work was also started on advanced forming of aluminum. Long-term R&D needs identified by the United States Automotive Materials Partnership are being addressed, especially process modeling, material performance modeling, recycle technology, and new materials development.

ORNL tasks in tribology include two CRADAs to evaluate the friction and wear of carbon graphite and in situ reinforced silicon nitride materials. This project will end when the CRADAs are completed in FY 1994.

Alternative fuels R&D involves a CRADA on improved catalysts and emission controls with General Motors, AC Rochester Division. Catalysts for natural gas and alcohol fuels are emphasized, and the R&D includes materials characterization, bench tests, and detailed measurements of catalyst performance on test stands. A comparison of on-road emission characteristics of conventional and alternative-fuel engines will begin in FY 1996.

Work in automotive propulsion technology complements our work on alternative fuels utilization by examining and testing concepts for advanced engines. ORNL has project management responsibility for heavy-duty engine emission aftertreatment and alternative fuel technology. New CRADA efforts are expected in the recently formed advanced automotive piston engine program. ORNL is also investigating space conditioning systems that are non-polluting, cost-effective, and energy conserving. A new application arising from this study is the liquid-overfeed mobile air conditioner that is 20% more energy efficient than existing air conditioners and uses non-CFC refrigerants. Tests of an advanced climate control system will begin in FY 1995.

The Advanced Propulsion Technology Center, part of the Oak Ridge Centers for Manufacturing Technology, serves as a development, integration, and evaluation facility for new technologies related to internal combustion engines and powertrains. These technologies include alternative fuels, new materials, diagnostics and controls, and other techniques for reducing emissions and enhancing efficiency.

ORNL also conducts analyses of transportation data and energy use related to vehicle and engine R&D and fuel economy, sales, and technology trends. Key transportation energy use data are published in the annual *Transportation Energy Data Book*. Major transportation databases are maintained by ORNL for use by the Office of Transportation Technologies. ORNL also provides policy analyses and assessments of fuel economy and clean air considerations.

In recognition of the vital role that transportation plays in the United States, Martin Marietta Energy Systems, Inc., has identified transportation as a major opportunity and established the Oak Ridge Transportation Technology Center (ORTRAN) with the goal of establishing Oak Ridge as a center of excellence in transportation R&D.

Initiative

Oak Ridge Transportation Technology Initiative

The transportation sector is a key area for energy resources, environmental quality, and industrial competitiveness. Transportation accounts for over 60% of the petroleum used by the United States and for over 30% of all energy use. It also accounts for at least 60% of some types of urban air pollution. Transportation is a vital part of U.S. industry; the domestic automobile industry accounts for about one of every seven jobs in America. In addition, improvements in the transportation infrastructure can improve mobility, increase fuel economy, and reduce highway accidents.

The capabilities of DOE's national laboratories, including ORNL, are a natural match for the needs of the transportation sector. To make these capabilities readily available, ORNL has joined with the other DOE Oak Ridge facilities, the Oak Ridge Y-12 Plant and the Oak Ridge K-25 Site, to create the Oak Ridge Transportation Technology Center (ORTRAN).

ORTRAN's goal is to be a center of excellence in transportation R&D and deployment, recognized for providing solutions to economic, environmental, energy, education, and safety challenges facing the region, the nation, and the world. To achieve this goal, ORTRAN will forge partnerships within the Oak Ridge complex and with other public and private agencies and industry, with emphasis on six development areas:

- advanced vehicle and fuel technologies,
- advanced defense transportation and deployment systems,
- hazardous materials transportation and handling,
- transportation policy and planning,
- intelligent vehicle highway system technologies and information systems, and
- transportation manufacturing and construction technologies.

The challenge is to develop new transportation technologies that will provide improved efficiency and safety and be much more environmentally sound in their manufacture, use, and disposal than current methods.

Budget projections for ORTRAN are shown in Table 5.10.

Table 5.10
Budget projections by fiscal year for ORTRAN
($ in millions)

	1995	1996	1997	1998	1999	2000
DOE funding[a]	55.3	67.8	63.0	68.2	72.4	76.7
Non-DOE funding[b]	15.4	18.1	21.5	25.0	28.9	30.6
Total	70.7	85.9	84.5	93.2	101.3	107.3

[a]Funding sources: DOE-EE, DOE-DP, DOE-EM, DOE-RW, DOE-EH, DOE-ER, and DOE-PO.
[b]Funding sources: U.S. Department of Defense, U.S. Department of Transportation.

Technical and Financial Assistance—EF

ORNL provides evaluation and technical support for several programs in the Office of Technical and Financial Assistance. The major current effort is a national evaluation of the Weatherization Assistance Program. Data on a nationally representative sample of program participants and matched control groups were collected and analyzed; estimates of energy

savings and cost-effectiveness were published in FY 1994. The Weatherization Assistance Program also sponsored ORNL's development of a National Energy Audit (NEAT). ORNL has provided NEAT and user training to the State Energy Offices and will continue to enhance NEAT in response to user feedback. ORNL research for the Energy-Related Inventions Program focuses on estimating the program's economic, energy, and environmental impacts. ORNL is also developing a continuous improvement strategy for service operations and delivery and is designing monitoring and assessment protocols for measuring customer satisfaction and service quality. Technical and management assistance is provided to the Committee on Energy Efficiency Commerce and Trade.

Utility Sector—EK

ORNL's research and outreach on integrated resource planning (IRP) for electric utilities includes projects on the effects on utility shareholders of different types of resource acquisitions, under both traditional regulation and a more competitive environment; how IRP and demand-side management (DSM) programs might change as the industry becomes more competitive; the treatment of uncertainty in analysis and acquisition of resources; and improved methods to evaluate DSM programs. ORNL has proposed a study of district heating, cooling, and cogeneration to determine energy, economic, and environmental benefits in accordance with the Energy Policy Act of 1992.

5.1.2.2 • Assistant Secretary for Fossil Energy

ORNL programs for the Assistant Secretary for Fossil Energy (DOE-FE) cover research in coal, gas, petroleum, and innovative clean coal technology, plus support to the Strategic Petroleum Reserve. The principal focus of ORNL's fossil energy activities, however, is coal. Budgets in this area are expected to increase, primarily because of additional efforts in materials and bioprocessing of coal.

Coal—AA

Significant programs are under way in materials research, bioprocessing, coal combustion, and environmental analysis support (EAS). A strong budget position has been maintained in materials research, and bioprocessing is experiencing growth. Support for coal combustion and EAS is expected to remain steady over the next five years.

The ORNL Fossil Energy Program has the technical lead and responsibility for technical management with DOE's Oak Ridge Operations Office for the Fossil Energy Advanced Research and Technology Development Materials Program. This program covers (1) traditional structural materials R&D on ceramic composites and advanced alloys and (2) functional materials (i.e., materials that possess properties important to performance of a specific function, such as solid-state electrolytes and inorganic membranes).

Fiber-reinforced ceramic composites with improved strength and toughness are being produced by the forced chemical vapor infiltration and deposition process developed at ORNL. Ceramic composites have a variety of applications in fossil energy systems; these include high-temperature heat exchangers and hot-gas cleanup filters.

Current work also emphasizes understanding the nature of the fiber-matrix interface with the aim of improving the mechanical properties of composites. Ceramic membranes for the separation of gases in high-temperature and hostile environments are being developed and

tested. Development is under way on carbon fiber composite molecular sieves, fabricated from fibers produced from petroleum and coal-derived pitches. The feasibility of microwave-assisted chemical vapor infiltration of ceramic preforms is being explored.

ORNL is developing advanced austenitic alloys for use in fluidized-bed and pulverized coal combustion power plants, with the objective of modifying existing alloys so as to provide the strength and corrosion resistance needed in high-temperature, high-pressure, second-generation power plants. Intermetallic alloys, primarily iron aluminides, are being developed for applications in which superior oxidation and sulfidation resistance and strength are required. Improved room-temperature ductility, resistance to hydrogen embrittlement, and fabricability will continue to be emphasized in the next several years.

Corrosion research at ORNL centers on studies of the formation and breakdown of protective oxide scales, particularly in sulfur-containing atmospheres, and on the effect of environment on corrosion of iron aluminides. An understanding of the properties and characteristics of oxide scales is evolving.

ORNL is committed to transferring the technology developed in the Fossil Energy Materials Program to industry and to others in the fossil energy community. A number of licenses and CRADAs have been executed, and several CRADAs are under discussion. A recently established CRADA with Cummins Engine Company involves direct-energy-regenerated particulate trap technology.

In the EAS area, ORNL provides technical and analytical support to the Morgantown Energy Technology Center (METC) by evaluating environmental concerns related to coal research and development projects and by preparing National Environmental Policy Act (NEPA) assessments of the projects. ORNL has completed a draft environmental assessment for the Warren Station demonstration project.

Growth continues in bioprocessing for coal conversion and utilization at the ORNL Bioprocessing Research and Development Center. Activities include the conversion of coal to useful liquid and gaseous fuels as well as the removal of heteroatoms and hazardous materials from coal, coal liquids, combustion gases and other gaseous and liquid effluents and products. Innovative microbial and biochemical pathways for bioprocessing concepts are being investigated for use in these areas, and advanced bioreactor systems that can efficiently and economically carry out such processes are being developed. Over 40% of some types of coal can be converted to liquids by reduction processes catalyzed by modified enzymes that can operate in organic solvents. Other biocatalytic systems can remove much of the organically bound sulfur that contaminates coal-derived liquids. Cooperative research with academic and industrial researchers is being conducted in almost all phases of this bioprocessing effort.

Molecular hydrogen is a valuable chemical feedstock for the liquefaction of coal and for hydrocracking and hydrotreating of petroleum. Virtually all hydrogen used in current processes is itself derived from natural gas. Current research is focused on the production of molecular hydrogen via photosynthetic water splitting; ORNL staff have recently demonstrated hydrogen production in an evacuated photobiological reactor. The great advantage of this technology is that it eliminates the need for an inert carrier gas and demonstrates the inherent ruggedness of unicellular microalgae from a real-world engineering perspective. This research also receives support from the Assistant Secretary for Energy Efficiency and Renewable Energy (DOE-EE).

Coal combustion research includes technical support to the Pittsburgh Energy Technology Center (PETC) for projects in India, directed primarily to the adaptation of DOE clean coal technologies for power generation using high-ash Indian coals; a CRADA project

with Babcock & Wilcox on the analysis of fluidized-bed combustion data for deterministic chaos; and METC-funded collaborations with other university and industrial partners to develop improved fossil energy process control through application of chaos theory.

Technical assistance is being provided to the PETC in the implementation of collaborative coal projects in India under a cooperative agreement between the U.S. Agency for International Development and the Government of India. We anticipate that this work will continue through FY 1995.

Gas—AB

The development of advanced turbine systems for power generation is the objective of a new program, jointly initiated by DOE-FE and DOE-EE in FY 1994. The objective of the Advanced Turbine System (ATS) Program is to develop ultrahigh-efficiency, environmentally superior, cost-competitive gas turbine systems for utility and industrial applications. A supporting element of the ATS Program is the Materials/Manufacturing Technologies Task, which is being coordinated by ORNL to address critical materials and manufacturing issues for both industrial and utility gas turbines.

Petroleum—AC

Technical support is provided to the Oil Technology Program. The program's goal is to maximize the economic producibility and processing of domestic oil resources by implementing a research, development, and demonstration plan in collaboration with state governments, industry, and academia.

A bioprocessing R&D program is being developed for treating petroleum, petroleum-derived products, and effluent streams. The most significant effort is a cooperative research program for the removal of sulfur, nitrogen, and other contaminants from crude petroleum and other refinery streams. This program involves a CRADA with several major oil companies through the Petroleum Environmental Research Forum, a collaborative effort on the part of these companies. ORNL plans to extend its advanced membrane technology to the separation of hydrogen, a costly ingredient in upgrading oil, from various refinery gas streams.

Innovative Clean Coal Technology—AZ

Work on the Clean Coal Technology Program (CCTP) includes support in the areas of environment and materials. The CCTP is jointly funded by DOE and industrial organizations. All five planned solicitations have been completed by DOE. An important part of ORNL's involvement in the CCTP is environmental technical support to DOE in the preparation of NEPA assessments of site-specific projects. Materials failure analyses (critical to the success of clean coal technologies) continue to be conducted for the PETC.

Strategic Petroleum Reserve—SA

ORNL provides assistance to the Strategic Petroleum Reserve Program in the assessment of alternative methods of financing oil acquisition and in the development of models for planning the capacity and management of the Strategic Petroleum Reserve.

5.1.2.3 • Office of Nuclear Energy

The Office of Nuclear Energy (DOE-NE) is the major sponsor of applied nuclear research at ORNL. Programs funded through this office are multidisciplinary and include nuclear reactor development, both civilian and naval; space nuclear power; and isotope production and distribution. Support is sought from DOE-NE for the initiatives for the Center for Excellence in Research Reactors and Retention of the Pool Critical Assembly, discussed in Sect. 5.1.1.1.

Nuclear Energy R&D—AF

Commercial Reactor Programs • Improved safety, performance, and availability for light-water reactors (LWRs) represent an important national need. Responsibility for the evolution of LWR designs is primarily in the hands of industry; DOE funds design certification and review tasks. ORNL's involvement in LWR development is primarily in the role of design reviews, cost studies, and development of specialized technologies such as passive design features and improved controls systems.

The emphasis of the national modular high-temperature gas-cooled reactor (MHTGR) program is now on a gas turbine direct cycle plant, the Gas Turbine–Modular Helium Reactor (GT-MHR), with a higher core outlet temperature (850°C vs 750°C) and power level [550–600 MW(t) vs 350–450 MW(t)] than the previous steam cycle system. The higher plant efficiency (approaching 50%) associated with the GT-MHR results in calculated power costs that are competitive with or better than the power costs of LWRs and fossil plants. Further, all of the safety and investment protection features characteristic of the steam cycle MHTGR are maintained or bettered in the GT-MHR. Program emphasis in FY 1995 will be on basic science and fuels development, with a search for new roles in modular helium reactor fuels. The HRB-22 fuel irradiation experiment completed in May 1994 is expected to provide important data to the international high-temperature gas-cooled reactor community.

Initiative

Improvement of the Safety and Economic Performance of Nuclear Power Plants through Digital Instrumentation and Control

The DOE Office of Nuclear Energy and the Electric Power Research Institute (EPRI) are discussing a joint program to apply modern instrumentation and controls (I&C) to improving the operational safety of nuclear plants. Most existing nuclear plants are finding it necessary to replace their aging I&C systems because of operational and maintenance problems and lack of spare parts. Equipment suppliers for I&C have replaced old product streams with digital-based products that have not been approved for nuclear applications. ORNL and EPRI have a CRADA to perform joint R&D in this area (see Sect. 5.2.2.1), but a much larger initiative is needed. This initiative will be part of a national program involving other national laboratories, several universities, and industry. Budget projections are given in Table 5.11.

Table 5.11
Budget projections by fiscal year for the Digital I&C Initiative[a]
($ in millions — BA)

	1995	1996	1997	1998	1999	2000
Total funding	1.0	2.0	2.5	3.0	4.0	4.0

[a]Funding is being sought from the Office of Nuclear Energy through program AF, Nuclear Energy Research and Development.

Radioisotope Thermoelectric Generator Production • ORNL continues to provide technical support for the development and fabrication of isotopic-powered systems. For space missions and terrestrial applications that use heat generated by isotopic power devices, the primary emphasis is on development of improved materials. Activities include the production of iridium alloy clad vent sets to contain heat-generating radioisotopes and carbon-bonded carbon-fiber thermal insulators capable of effective operation at 1300°C. Production of these materials began in FY 1990 and is anticipated to continue through 1995 in support of NASA's Cassini missions. ORNL has teamed with the Oak Ridge Y-12 Plant to define new Oak Ridge roles in the Radioisotope Power Systems Program, including ^{238}Pu production in the High Flux Isotope Reactor (HFIR) with target reprocessing in the Radiochemical Engineering Development Center.

Naval Reactors—AJ

Radiation Shielding Information Center • The Office of Naval Reactors (NE-60) provides some funding for the Radiation Shielding Information Center (RSIC), which supplies specialized information, computational tools, and a suitable cross-section database to DOE programs by serving as a focal point in the community for technology exchange and making available the latest developments in computing and other technology, data libraries, and bibliographic information. RSIC is described in Sect. 5.1.6.2.

Isotope Production and Distribution Program—ST

The mission of the Isotope Production and Distribution Program at ORNL is to supply enriched stable isotopes, selected radioisotopes, and related technical services for research, medical, and industrial applications. This continues to be a significant and highly valued program that uses the unique capabilities and facilities located at ORNL. Radioisotopes for many uses, including medical research, are produced in HFIR; enriched stable isotopes can be produced in the Calutrons (now on standby) located in the Isotope Enrichment Facility. The program mission includes the development and evaluation of methods for isotope production and separation. Specialized technical services such as preparation of high-purity isotopes and unique chemical and physical forms are also performed.

The program has operated since 1990 under a revolving fund arrangement, with the expectation that the program would be self-supporting. Competition in the marketplace from foreign suppliers, the lack of capital funds for expanding and improving program operation, and rising production costs over which the program has no control have placed the Isotope Production and Distribution Program in jeopardy. Following an examination of the program by the General Accounting Office, the Arthur Andersen Company, and KPMG Peat

Marwick, as well as Congressional hearings to examine the problems being encountered, the Isotope Production and Distribution Program is being restructured by DOE-NE.

5.1.2.4 • Energy Information Administration

ORNL will continue its support of the Energy Information Administration (EIA) through (1) economic analysis in support of issue analysis and in support of EIA's ongoing energy modeling activity, (2) analysis and evaluation of EIA's quality assurance activities, particularly through expert reviews, and (3) technical analyses including engineering studies. In addition, ORNL will apprise EIA of new developments in the following areas of expertise:

- energy, environmental, and economic modeling,
- information systems development,
- creative file structures and maintenance,
- artificial intelligence and expert systems,
- development of an international energy database through the ORNL–U.S. Agency for International Development program (see Sect. 5.2.1.8), and
- a growing number of analyses of technological change.

A National Energy Information System would provide a coordinated approach and a center of responsibility by which the objectives and technical needs of the EIA may be met. Funding for future years is expected to be stable in real dollars.

5.1.2.5 • Office of Civilian Radioactive Waste Management

Nuclear Waste Fund—DB

ORNL's work in support of the DOE Office of Civilian Radioactive Waste Management (OCRWM) is funded by the Nuclear Waste Fund (program DB) and through work for others (WFO). ORNL's current activities involve waste and facility information and databases (DB03), systems engineering, environmental technical assistance, and strategic and contingency planning (DB09), and transportation and systems engineering (WFO). OCRWM has transferred many of its activities to its management and operating contractor. The transportation and systems engineering work in the WFO area is being performed under a memorandum purchase order arrangement with this contractor. Funding is expected to remain level during the planning period.

Work in the DB03 area involves support for waste and facility information and databases, including completion of the Facility Interface Capability Assessment (FICA) work, continuing support of the Integrated Data Base (IDB), and support of transportation-related institutional activities. The FICA has resulted in the development of a global assessment of the ability of the nation's 122 reactors to accommodate various spent fuel shipping casks. The IDB is jointly funded and provides a comprehensive, top-level perspective on the wastes that must be handled by DOE in the future; it contains DOE's official spent fuel and radioactive waste inventories and projections through 2020.

Transportation support involves studying the development of support systems, assessing systems alternatives, and supporting the testing of a tractor for pulling a legal-weight highway cask system. One major area will be the continued development of site-specific services planning documents for defining specific logistical interfaces between cask systems and reactor handling facilities. In addition, support will be provided in assessing the development of the multipurpose container system design concepts, in the development and

maintenance of computer models needed by the OCRWM transportation project, and in supporting a case before the Nuclear Regulatory Commission for allowing burnup credit in cask designs.

Systems engineering efforts in both the DB09 and WFO areas are focused primarily on improved applications of the ORIGEN21 code used for projecting radionuclide inventories and on verifications and validation. Environmental technical assistance in the DB09 area involves continuing support in evaluating environmental aspects of the high-level waste management program. Strategic and contingency planning provides support in preparing and evaluating plans and strategy reviews of the OCRWM program.

5.1.2.6 • Power Marketing Administrations

Bonneville Power Administration

ORNL's Energy Division conducts program evaluation research for the Bonneville Power Administration's Office of Energy Resources. Bonneville has operated a Residential Weatherization Program since 1981. ORNL's research evaluated the energy saved by this program over time and has expanded into issues concerning the energy efficiency of new residential buildings, compliance with Bonneville's Model Conservation Standards, the fuel choices of customers, and integrated resource planning. The ORNL Energy Division will extend its leadership in the fields of artificial intelligence and power systems by developing a system to monitor Bonneville's substation equipment in real time to support reliability-centered maintenance.

5.1.3 • National Security and Environmental Management Programs

5.1.3.1 • Assistant Secretary for Defense Programs

Weapons Activities—GB

Radiation Shielding Information Center • The Radiation Shielding Information Center provides in-depth coverage of the radiation transport field and serves the needs of a variety of disciplines on an international basis. See Sect. 5.1.6.2 for additional information.

Technology Transfer Initiative • The objective of the Technology Transfer Initiative (TTI) is to conduct R&D that will benefit both programs sponsored by the Assistant Secretary for Defense Programs (DOE-DP) and the private sector. ORNL is engaged in a number of CRADA projects in collaboration with the Oak Ridge Y-12 Plant, focusing on manufacturing. Project teams are made up of staff from ORNL and Y-12 in roughly equal numbers, with leadership provided by the organization with the critical elements for the technology development and transfer process.

As part of the TTI, ORNL operates the Ultraprecision Manufacturing Technology Center, which is dedicated to developing and validating manufacturing processes that can be used to produce affordable, high-quality components. Technical areas of concentration include precision turning, ductile grinding, ion beam milling, on-process characterization, mechanical design and analysis, and related efficient manufacturing operations. This center is a DOE Deployment/User Facility, where participants from industry, universities, and government perform cooperative, hands-on activities. This concept makes it possible for the private sector to reap the benefits of new technology without incurring the time, expense, and risk of the "trial-and-error" approach to improving manufacturing processes. The Ultraprecision

Manufacturing Technology Center is part of the Oak Ridge Centers for Manufacturing Technology (see Sect. 5.1.6.4).

The ORNL Office of Laboratory Computing coordinates ORNL's participation on the DOE-DP Technology Area Coordinating Team for Computing Architecture and Applications. This team has identified several priority areas: gigabit network technology, materials by computer design, automotive design and manufacturing, software tools, and banking.

The Office of Laboratory Computing coordinates the distribution of some of the DOE-DP block grants now being awarded. The first such grant is supporting work in collaboration with the gas and oil industry, focusing on National Information Infrastructure (NII) technologies. The goal of the Gas and Oil NII Project is to apply DOE's computational research and system integration abilities in advanced information technologies to U.S. industry issues. In cooperation with Los Alamos National Laboratory (LANL), Lawrence Livermore National Laboratory (LLNL) and Sandia National Laboratories (SNL), ORNL and Y-12 are researching dual-use infrastructure needs applicable to both the defense industry and the geographically distributed gas and oil industry. This project consists of a multilaboratory development of a Synthetic Seismic Dataset for standardized benchmarking, forming the basis for a computing and communications testbed with the gas and oil industry. Additional projects address network infrastructure needs including:

- data-distributed visualization and computational steering (as an acceptable front end to massively parallel computing environments),
- virtual reality (interactive immersion environments for scientific investigation and communication),
- remote collaboration environments (to allow geographically distributed scientists and managers access to the same "objects" on their workstations),
- network applications to benchmark the application performance of these NII tools, and
- on-line information services (to provide access to information within this project).

Some interactivity between these projects will occur as the tools developed in one project will be applied in another.

Materials Production—GE

The materials production program includes the ^{252}Cf Industrial Sales/Loan Program (co-sponsored by the Office of Energy Research and discussed in Sect. 5.1.1.1), the Mark 42 Processing Program, and the ^{233}U Storage and Distribution Program.

The Mark 42 Processing Program involves the recovery and purification of transuranium element isotopes (^{242}Pu, ^{243}Am, and ^{244}Cm) from Mark 42 targets that were previously irradiated at the Savannah River Site and segmented at Pacific Northwest Laboratory. The Mark 42 targets are processed to recover light transuranium element isotopes for use in weapons diagnostics at LANL and LLNL. Targets are processed at the rate of about one target every two years. Processing began in 1991; ultimately, ten targets will be transferred to the Radiochemical Engineering Development Center for storage and processing.

Shielded, safeguarded storage and some distribution of ^{233}U continue in the Radiochemical Development Facility (Building 3019) at ORNL. Equipment for processing ^{233}U has been in standby since 1989. Plans are being developed to improve the condition of the aging facility to ensure safe, long-term storage and distribution of ^{233}U.

5.1.3.2 • Office of Nonproliferation and National Security

Verification and Control Technology—GC

The Office of Arms Control and Nonproliferation is supporting efforts to develop rapid, portable methods for detection of airborne chemical agents. Health Sciences Research Division staff have been applying the technique of surface-enhanced Raman spectroscopy to this problem. Laboratory work has revealed the technique to be both rapid and sensitive. Field tests are needed to see if there is sufficient selectivity under real-world conditions.

Nuclear Safeguards and Security—GD

ORNL is transferring to industry a maturing technology that makes possible high-sensitivity/high-specificity detection of the vapors of high explosives and other contraband. This technology can detect explosives vapors at concentrations as low as a few parts per trillion with essentially no false alarms.

The Office of Security Affairs is supporting the development of frangible non-lead ammunition, an enclosed-space detection system, a field-ready diversionary device (the MK-141 Flash Bang grenade), research on technical and security aspects of database management, multilevel secure network design, and information systems security training.

5.1.3.3 • Office of Fissile Materials Disposition

Fissile Materials Disposition—GA

A program has been established at ORNL to support the new DOE Office of Fissile Materials Disposition (DOE-MD). ORNL has been identified as the lead laboratory for storage and disposition of ^{233}U and minor actinides (transuranic elements other than plutonium) and for reactor-based technologies for disposition of surplus plutonium. In these roles, ORNL will have cradle-to-grave responsibility for leading the evaluation and implementation of U.S. strategies for reducing the inherent proliferation potential of these DOE materials. Additionally, ORNL has been charged with the development of an advanced vitrification technology for plutonium and is supporting LANL, LLNL, and SNL in the development and assessment of other plutonium handling technologies. The ORNL role complements the Oak Ridge Y-12 Plant's role for DOE-MD as lead DOE organization for the disposition of surplus highly enriched uranium (HEU).

The program includes the following elements.

- Reactor-based disposition of plutonium. ORNL will lead the DOE effort to evaluate reactor options for converting plutonium into spent fuel and characterize them for a programmatic environmental impact statement. These options include mixed-oxide (MOX) fuel in existing or partially completed U.S. light-water reactors (LWRs), MOX fuel in CANDUs, MOX fuel in newly constructed advanced LWRs, graphite fuel in a modular helium reactor, and "deep burn" options in dedicated molten salt reactors or the particle bed reactor. Factors to be addressed include performance, environmental impacts, cost, timeliness, and technical risk.
- ^{233}U and minor actinides. ORNL will lead a multilaboratory effort to characterize inventories of ^{233}U and minor actinides and to identify options for reducing their proliferation and for their eventual disposition; the Idaho National Engineering Laboratory, LANL, LLNL, and SNL will provide support. ORNL will develop a program plan and define the

roles and funding for all participants. Early emphasis for ^{233}U will be on defining blend-down technologies to render the material unusable for weapons. The blend-down process for ^{233}U differs from that for HEU because of the different chemical forms of the ^{233}U and because the down-blended ^{233}U product will be waste rather than LWR fuel. Options for direct disposition of ^{233}U and minor actinides to the Waste Isolation Pilot Plant or other waste facilities will be examined. Methods for blending fissile materials with existing DOE stocks of high-level liquid waste and for irradiating materials in DOE reactors will be examined and characterized.

- Vitrification of plutonium. ORNL will develop and characterize a novel technology for vitrifying metallic plutonium without the currently required step of converting the plutonium into an oxide. Potential benefits of the technology include lower cost, reduced environmental impact, and improved international verification of plutonium operations.
- Accelerator-based conversion of plutonium. ORNL will support the Brookhaven National Laboratory (BNL) and LANL is the development of advanced technologies for the accelerator-based fissioning of plutonium. ORNL will have lead development roles for plutonium-based graphite fuels in the BNL technology program and for plutonium-based molten salt technology, chemistry, and materials of construction in the LANL-led option. ORNL will also conduct systems analyses and perform preconceptual facility design for the nonaccelerator parts of the systems.
- Transportation technologies. ORNL will define transportation technologies and evaluate transportation operations and risks for all transportation legs in program options that involve low-level or high-level radioactive materials. This task will include transportation of spent MOX fuel in reactor operations, transportation of glass logs with plutonium and high-level waste for immobilization options, and shipments of cesium capsules and low-level waste for several options.
- Economic analysis and decision analysis. ORNL will define the cost accounting guidelines and perform life-cycle cost analysis for all disposition options evaluated by DOE. In addition, the ORNL program manager will serve as a member of the DOE screening committee for providing supporting assessments for decisions on the disposition of plutonium, HEU, ^{233}U, and minor actinides. ORNL will also support various DOE public outreach activities by providing technical experts to work with the public and with industrial stakeholders.

Rapid changes in the international nuclear materials situation continue to cause changes in U.S. priorities and strategies for fissile materials disposition. ORNL will continue to seek new roles and to investigate applications of new technologies to respond to these changing circumstances.

5.1.3.4 • Assistant Secretary for Environmental Management

ORNL receives funding from the Assistant Secretary for Environmental Management (DOE-EM) for (1) activities aimed at correcting existing problems, preventing future problems, and minimizing waste generation at the ORNL site, as described in Sect. 6.2, and (2) R&D and technical support for addressing environmental management problems, principally at DOE sites, with increasing emphasis on technology transfer to the public and private sectors. Much of this activity is conducted through the Center for Risk Management in ORNL's Health Sciences Research Division and through the Center for Environmental Technology, in which ORNL plays an integral role. Both centers are discussed in Sect. 5.1.6.4.

Environmental Restoration

The ORNL site Environmental Restoration Program integrates activities supporting transition of inactive facilities for decontamination and release or for demolition with remedial actions for contaminated sites. The program's primary goal is protecting human health and the environment. The ORNL Environmental Restoration Program teams with the Waste Management Division to provide a comprehensive environmental management program for the ORNL site. The program takes full advantage of the scientific and technical resources at ORNL to meet the local environmental restoration challenges, and it strives to fundamentally improve the process of environmental restoration. Innovative approaches are developed and used to focus and streamline decision making to provide safe and cost-effective risk reduction. The program supports the development and demonstration of technologies for characterization and remediation of sites and facilities, and collaborates with efforts supported by the DOE Office of Technology Development to demonstrate and/or employ new tools in the remediation process.

In conjunction with the ORNL Surplus Facilities Management Program (SFMP), the ORNL Environmental Restoration decontamination and decommissioning (D&D) program provides surveillance and maintenance to ensure the safety of DOE sites awaiting decontamination, planning the orderly decommissioning of facilities, and a program to accomplish disposition of all facilities. Activities related to cleanup at the ORNL site are described in Sect. 6.2.

ORNL provides support for DOE-EM activities beyond the boundaries of the ORNL site via several remedial action projects (RAPs). Major ORNL activities in RAPs include conducting radiological surveys on private properties near inactive mill tailings sites [Uranium Mill Tailings Remedial Action Project (UMTRAP)] and at facilities that were formerly used under contract with the Atomic Energy Commission [Formerly Utilized Sites Remedial Action Project (FUSRAP)]. The radiological status of sites involved in DOE's RAPs is identified, characterized, and verified to provide a basis for reducing the health impacts of fuel cycle activities. Advancement of the state of the art in equipment and methodology is an integral part of this work.

In support of these activities, ORNL maintains an office in Grand Junction, Colorado. The Grand Junction office leads an effort to identify properties near 24 inactive uranium mill sites and recommend their inclusion in UMTRAP. Most of the inclusion surveys have been completed. The Grand Junction office is also responsible for verifying the adequacy of remedial actions taken to address contamination in excess of relevant Environmental Protection Agency (EPA) criteria and DOE guidelines at UMTRAP sites and at western sites accepted into the SFMP. An ORNL group based in Oak Ridge carries out the equivalent functions for radiologically contaminated sites in the FUSRAP and at eastern sites accepted into the SFMP.

Funding for FUSRAP is expected to remain level through FY 1995. SFMP funding is expected to increase as the level of decommissioning effort at federal facilities increases. ORNL will verify that these facilities are decontaminated in accordance with established DOE guidelines.

New approaches, processes, and technologies are required to tackle many of the pressing environmental restoration problems facing DOE. R&D coupled with demonstration, testing, and evaluation (RDDT&E) is critical to fostering cost-effective solutions to these problems. An important part of the ORNL effort is directed toward RDDT&E in direct support of real problems at DOE sites.

If decontaminated facilities are to be released for unrestricted use, well-documented clearance criteria will be needed. Establishing these criteria will require a definition of the relationship between residual surface contamination and the absorbed dose resulting from skin absorption, ingestion, or inhalation of dust or vapors from surfaces. Staff members in the ORNL Health Sciences Research Division are applying their expertise in radiological surveying and indoor air quality to make measurements and refine models that will be used to develop this definition.

The Energy Systems Groundwater Program Office (GWPO) promotes consistency among groundwater activities at the DOE facilities managed by Energy Systems and acts as a focal point for technical and programmatic interactions with the public and with state and federal regulatory agencies. Groundwater protection program coordinators at each site are responsible for oversight of all groundwater activities at their sites and for facilitating integration of requirements of the compliance and environmental restoration groundwater programs. The Oak Ridge Hydrology Support Program provides technical support to the GWPO to assist in achieving technical consistency and defensibility across the site programs and to facilitate the sharing of lessons learned. Both of these programs are managed through ORNL's Environmental Sciences Division.

Waste Management

Waste management activities at ORNL are discussed in Sect. 6.2. These activities include the operation of 34 facilities, ongoing upgrades of ORNL waste management facilities needed to support the programmatic missions of DOE, management of wastes produced by previous operations and research, and waste minimization activities.

Technology Development

The DOE-EM Office of Technology Development is charged with developing and demonstrating new technologies for dealing with DOE's environmental management problems. The ORNL Office of Environmental Technology Development, one of five offices in the Center for Environmental Technology (see Sect. 5.1.6.4), manages a diverse program of technology development to address these problems. The program involves developing new technologies and demonstrating or modifying existing techniques to ensure application of the most cost-effective and technologically advanced remediation and waste management methods. This work is conducted at ORNL, the Oak Ridge Y-12 Plant, and the Oak Ridge K-25 Site. The technologies being developed are shared among DOE sites and with the private sector for use in solving similar environmental problems. Program components include:

- Treatability—inorganic membrane technology for in situ remediation of chromic acids, heavy metals, volatile organic compounds (VOCs), and other organics in landfills; in situ immobilization, thermal treatment, and/or advanced oxidation methods for the treatment of soils contaminated with VOCs and low levels of radioactive substances; and in situ vitrification to instantly destroy many hazardous components and immobilize the remainder in a glass or slag matrix.
- Characterization—modeling of hydrologic systems; advanced field measurement and sensing methods; improved systems for data collection, analysis, management, and display; biomarker and biosensor instrumentation to monitor contaminant behavior and response to remediation strategies using improved, less costly, analytical means in situ

and in real time; and field-oriented methods that allow characterization of sites and contaminants with minimal cost, health, and safety impact.

- Bioremediation—microorganisms that can fix, degrade, detoxify, or accumulate select organic materials [e.g., tetrachloroethylene, trichloroethylene, polychlorinated biphenyls (PCBs)] and inorganic materials (e.g., uranium, strontium, cesium, lead, cadmium, copper) in situ or in process.
- Robotics—robotic systems and remote technology that can enhance environmental restoration and waste management operations by removing workers from radioactive, hazardous, and mixed waste; increasing speed and productivity of characterization and remediation; and reducing life-cycle costs.
- D&D—decontamination and decommissioning of metals and concrete to assist in the decommissioning of formerly utilized facilities.
- Waste minimization—action that minimizes the volume or toxicity of waste by recycling, recovery, and reuse of materials; source substitution; and process modification to reduce the production of radioactive, hazardous and mixed wastes at the generation point.
- Transportation—database evaluation and site verification to develop an understanding of site-specific needs; systems engineering to evaluate methods of meeting transportation requirements for a reasonable number of applications, including hazardous and mixed waste remediation efforts; risk assessment and regulatory support to systematically define the requirements for on-site and off-site transport of hazardous and mixed waste; and base technology development to evaluate the effect of hazardous substances on packaging components.
- Technology transfer—facilitation of the transfer of technologies that could improve program and operational effectiveness, reduce costs, and save time, among federal agencies, industry, academia, and the international community.

Although some of the technologies mentioned here are currently developed, much more refinement and advancement are necessary for their cost-effective application to increasingly challenging waste problems. Significant industrial involvement is expected, especially during the demonstration phase of the technologies; this will require an efficient transfer of new technologies for application both to and from the DOE facilities.

In an effort to increase the number of qualified scientists and engineers, this program also sponsors joint research projects with universities and minority institutions to encourage students to study in fields applicable to environmental restoration and waste management.

Significant recent accomplishments include the deployment of the direct sampling ion trap mass spectrometer at the Oak Ridge, Savannah River, and Hanford sites for real-time monitoring of VOCs; demonstration of remote excavation of buried waste, deployment of the derivative ultraviolet absorption spectrometer for on-line monitoring at the Lawrence Livermore National Laboratory dynamic stripping site; and demonstration of ac swing-free crane robotic technology.

Funding is anticipated to increase slightly over the planning period.

Quality Assurance and Quality Control

The ORNL Environmental Sciences Division will assist the Office of Environmental Oversight in its EM-wide document review, guidance, training, and auditing functions. A high-priority activity in this area is development of guidance for efficiently integrating Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), National

Environmental Protection Act (NEPA), and Resource Conservation and Recovery Act (RCRA) documentation and requirements for EM activities.

5.1.4 • Environment, Safety, and Health

Assistant Secretary for Environment, Safety, and Health

Work is performed at ORNL for the Assistant Secretary for Environment, Safety, and Health (DOE-EH) in nearly a dozen organizations spread throughout the Laboratory structure. This work is coordinated by a program manager for all R&D and technical support activities funded by DOE-EH. The program manager reports directly to the Laboratory Associate Director for Environmental, Life, and Social Sciences. This focal point for communication and coordination provides an effective and responsive interface for the matrix of principal investigators and customers.

Environment—HA

Technical support activities for DOE-EH include regulatory analysis, analysis of environmental impacts of energy development, technical input to policy analysis, technical guidance on compliance with environmental regulations, and training.

Environmental Guidance and Compliance • ORNL will continue to provide technical support to the Office of Environmental Guidance. Work for this office encompasses a variety of regulatory activities, including the tracking and analysis of regulations and the development and dissemination of regulatory information and guidance. ORNL has provided substantial support for training in environmental laws and regulations, and the development and implementation of training courses in these areas for DOE and its contractors will continue. Efforts will focus on subjects important to DOE's environmental restoration program, such as RCRA closures and the Natural Resources Damage Assessment process.

ORNL also provides technical support to the Office of Environmental Guidance in standards and procedures development, calculational model validations, risk assessment, and radiation protection requirements. The Laboratory is developing a radiological survey procedures manual, which provides detailed specifications for measurement and assessment of radiological environmental pollutants. The manual will serve as the basis for radiological surveys at DOE and contractor facilities. ORNL staff also provide support to DOE's Risk-Based Standards Working Group, which is developing guidance on health and environmental risk assessments performed at DOE facilities.

ORNL has the capability to conduct large-scale hydrogeological and environmental characterization activities that are essential to addressing the contamination problems on many DOE sites. Increasing interaction with regulatory agencies is creating the need for a uniform, efficient, and well-organized approach to the development and initiation of site-wide characterization studies. ORNL plans to serve as the coordinating center for characterization of selected DOE sites throughout the country, drawing heavily on the experience developed in work done on the Oak Ridge reservation, which is hydrogeologically the most complex of any of the sites. ORNL technical support in emergency response R&D is available.

NEPA Oversight • ORNL continues to provide technical support to the Office of NEPA Oversight. This includes assistance with the development of guidance for compliance with NEPA, preparation of related background information, review of NEPA documents, and

assistance at DOE-HQ. A major initiative related to the DOE rule on NEPA compliance (10 CFR 1021) is assistance with the revision of the *NEPA Compliance Guide*. ORNL is developing audit protocols to assess compliance with NEPA at DOE facilities nationwide.

Environmental Audit • ORNL expertise in environmental and health risk analysis is available to help identify and prioritize actions required to comply with environmental regulations, Federal Facilities Agreements, and consent orders.

Safety and Quality Assurance • ORNL provides technical and administrative support for the ES&H Business Management and Budgeting Plan (formerly the Five-Year Plan) administered by DOE. Contributions include participating on the development team for the plan, developing a risk-based model to prioritize ES&H issues and projects, and training facility and field office personnel at DOE sites across the country.

The Laboratory provides technical and management assistance to DOE for several occupational safety and health (OSH) tasks: (1) development of new approaches to OSH program evaluation and management, (2) development of an OSH Handbook for DOE contractors that includes "how-to" information for contractors and for DOE staff and line organizations, (3) conduct of a "benchmarking" program of sharing notably effective OSH programs among DOE contractors, (4) development of response capability for a toll-free telephone number receiving requests for interpretations of OSH regulations, (5) establishment of DOE's equivalent to the Occupational Safety and Health Administration's Voluntary Protection Program, (6) implementation of an electrical safety program, and (7) ensuring that the safety and the health of workers and the public are protected during all DOE environmental management activities.

Transportation and Packaging Safety • Work at ORNL for the DOE-EH Transportation and Packaging Safety Division includes the Packaging and Transportation Program, which provides technical and management support for the hazardous materials–related transportation safety activities and responsibilities of DOE-EH as defined in DOE Order 5480.3. Oversight assistance is supplied to DOE by providing technical support and staffing of the assessment teams for DOE-EH site representatives' packaging and transportation performance assessments. Assistance is also provided in analyzing the packaging and transportation safety implications of reports submitted by contractors to the Occurrence Reporting and Processing System. ORNL has also been responsible for drafting a series of DOE Orders on the safety of the transportation and packaging of hazardous materials, explosives classification, on-site transport, and motor vehicle safety. Other DOE support from ORNL in the policy and guidance area includes continued work on a packaging design guide and the provision of technical and management support to various national and international guidance and standard-setting committees. Technical assistance to DOE includes technical reviews, preparation of papers, participation in programs, and preparation of management plans.

Support to the Transportation and Packaging Safety Division also encompasses maintenance and enhancement of the Standardized Computer Analysis for Licensing Evaluation computational system, SCALE. SCALE is used throughout the world in performing safety evaluations in the areas of nuclear criticality safety, radiation protection, radioactive material characterization, and heat transfer. Upgrades and corrections to the system are available to users through the Radiation Shielding Information Center at ORNL (see Sect. 5.1.6.2). A SCALE Users Training Course sponsored by the Transportation and Packaging Safety Division is conducted by project staff at ORNL. Course attendees include representatives from DOE, the Nuclear Regulatory Commission, national laboratories, and industry, plus a number of international participants.

Radiation Dosimetry • Dosimetrists and regulators alike recognize the need for improved neutron dosimetry. The ORNL Dosimetry Application Research (DOSAR) staff has continued to develop and further demonstrate the potential for bubble technology to meet this need and has proceeded toward development and application of appropriate devices. Material developed for use as three-dimensional (3-D) optical random-access memory (ORAM) in high-speed computers is also of interest to DOSAR scientists as a basis for a revolutionary neutron dosimeter. Their research in development and application of 3-D ORAM material as a neutron detector has the potential to provide a dosimetry method that allows precise neutron dose measurements that are independent of energy and could result in a replacement for both film and thermoluminescent dosimeters now in use.

DOE facilities at which the potential for a nuclear criticality accident exists are required to have nuclear accident dosimetry capabilities and to ensure that they function properly. The DOSAR staff is continuing its efforts to organize a Nuclear Accident Dosimetry Applications Test Program using the fast pulse reactor at the Army Pulse Radiation Facility in Aberdeen, Maryland. The proposed program is essential to provide for proper testing, education, and training throughout DOE.

Biostatistical Support for Health Studies • ORNL continues to provide the Office of Epidemiology and Health Surveillance (OEHS) with statistical support for programs in epidemiologic surveillance and occupational medicine. Statistical methods that are being developed to describe and evaluate illness and injury event data will be used by DOE's Epidemiologic Surveillance System, which will monitor the health of the work force at all DOE sites and will be used to identify health hazards in the work place.

OEHS is also conducting a follow-up study of beryllium workers at the Oak Ridge Y-12 Plant. The beryllium lymphocyte proliferation test (BLPT) is being used as part of a screening procedure to identify individuals who may have chronic beryllium disease. Statistical methods that will facilitate the evaluation of the BLPT are being developed. ORNL provides general biostatistical support to OEHS for the planning, analysis, and interpretation of studies related to health and environmental issues.

Nuclear Safety Policy and Standards—HP

DOE Technical Standards Program • Since the late 1960s, ORNL has led in the management and overall conduct of standards development efforts, first for the Atomic Energy Commission and now for DOE. In this position, ORNL assisted DOE in establishing the program procedures and guidance for all participating DOE and DOE contractor organizations to implement DOE's standards policy as outlined in Order 1300.2A, "Department of Energy Technical Standards Program." This order, updated in May 1992, reaffirms DOE's long-standing policy of using existing national/international standards wherever applicable and developing new departmental standards for its facilities, programs, and projects when necessary. ORNL responsibilities for the DOE Technical Standards Program are

- to function as the DOE lead standardization organization, serving as the focal point within the department for registering new and ongoing standards development activities and carrying out technical/administrative program management;
- to develop new program procedures for all involved organizations to follow in implementing the DOE standards policy;
- to develop and maintain a DOE standards database, identifying the various types of standards (international, nongovernment, federal, DOE, and program-specific) used or

available for use by DOE and DOE contractor organizations, DOE technical standards projects in progress, and departmental and contractor personnel involved in standards development activities;
- to develop and conduct training (initial and ongoing) for DOE and DOE contractor personnel on the DOE Technical Standards Program procedures; and
- to provide technical support for a DOE standards committee to arbitrate standards development/application issues that affect more than one department secretarial office.

DOE Performance Indicator Program • DOE, in a manner similar to the commercial nuclear industry, considers that facilities with good performance, as measured by an overall set of performance indicators, are generally recognized as well-managed facilities. The objective of DOE's performance indicator program is to collect data on key performance indicators and to have line management analyze and trend the data. ORNL compiles and prepares quarterly summary reports based on quarterly reports received from the senior officials in the DOE performance indicator program and performs special analyses of these data as requested.

Epidemiologic Activities—HR

Mathematical phantoms of pregnant women, developed in a collaboration between ORNL and the Oak Ridge Institute for Science and Education, can be used with a Monte Carlo computer code to determine the absorbed dose to the embryo/fetus. ORNL plans to use these mathematical phantoms to calculate dose factors for application in studies of 1945 atomic bomb survivors who were exposed *in utero*. The results should enhance the analysis of risk of cancer from prenatal exposure. Work will be performed in collaboration with the Radiation Effects Research Foundation in Japan.

5.1.5 • Other Department of Energy Programs

ORNL provides support to other DOE offices and installations, including the Assistant Secretary for Policy, Planning and Program Evaluation; the Office of the Associate Deputy Secretary for Field Management; the Federal Energy Regulatory Commission; other DOE contractors and operations offices, and other Energy Systems sites.

5.1.5.1 • Assistant Secretary for Policy, Planning and Program Evaluation

Policy, Analysis, and Systems Studies—PE

Work for the Assistant Secretary for Policy, Planning and Program Evaluation will include research on transportation, energy efficiency, infrastructure costs associated with alternative fuels, alternative fuels supply issues and effects on energy security, consumer choice and demand issues for alternative fuels, fuel economy standards for automobiles and light trucks, and energy options for developing nations. Research will continue on the effects of clean fuels and reformulated gasoline on the energy industry, consumers, and the environment. ORNL anticipates continuing work in support of DOE's role in assisting the Council on Environmental Quality in the development of a national strategy and plan for reporting long-term environmental trends. Additional support is provided in the area of regulatory analyses for hydropower development and environmental compliance issues.

ORNL supports the Office of Environmental Analysis in developing energy resource assessment models and providing background research for various energy and environmental policy issues. This office is funding a variety of projects, including a flue-gas desulfurization information system, development of a residual generating model for the National Energy Modeling System, studies of international developments in global climate change, research on the physical and ecological effects of climate change, research on the economic valuation of energy-related environmental impacts, and studies of the impacts of environmental policies on electric utilities. A major effort is in progress to analyze fuel cycles and to provide estimates of (1) the physical impacts on environmental resources, including human health and safety, and (2) costs and resulting potential effects on market prices for major fuels.

ORNL also provides support to the Office of Electricity/Coal/Nuclear & Renewable Policy on hydropower issues (e.g., by studying the feasibility of a hydropower environmental mitigation information analysis system). If DOE continues to support this concept, additional long-term funding may be received.

ORNL is actively involved in developing a DOE program related to the energy needs of developing nations. The Assisting the Deployment of Energy Practices and Technologies (ADEPT) Program includes needs studies, technical information, institution building, training, technology adaptation, and technology demonstration. ORNL roles include project activities and program support. In addition, ORNL is supporting the development of an Energy Efficiency Strategy Assistance Program.

5.1.5.2 • Associate Deputy Secretary for Field Management

In-House Energy Management—WB

ORNL is conducting energy management studies in Laboratory facilities to identify retrofit projects that will allow achievement of the energy consumption and efficiency goals established by DOE and reflected in ORNL's ten-year energy plan. The goals in the plan are addressed through a comprehensive Energy Management Program. The program's elements integrate energy conservation activities specific to ORNL's buildings, equipment, processes, and vehicles. Heating, ventilation, and air conditioning systems are being upgraded to improve their efficiency.

5.1.5.3 • Federal Energy Regulatory Commission—VR

ORNL provides assistance to the Federal Energy Regulatory Commission (FERC) in two major areas: evaluation of the environmental impacts of licensing new hydroelectric projects and compliance with environmental conditions at existing hydroelectric projects. Ongoing work includes several site-specific NEPA documents for hydroelectric projects in the Central Valley of California, where major water rights issues are being addressed; in the state of Washington, where multiple small-scale projects are proposed in the Skagit and Nooksack river basins; and in Montana, for a relicensing action in the Missouri and Madison river basins. This work involves development of complex water routing models and mitigation solutions to challenging issues such as biodiversity, the spotted owl, and water use for drinking vs maintenance of fish populations. Relicensing of existing projects has become a major effort for the FERC, and staff are also being challenged to define methods to enhance an environment that may have been affected by 50 years of hydropower operation.

5.1.5.4 • Other Programs

ORNL performs numerous small tasks, frequently on an ad hoc basis, for a number of other organizations within DOE, including the Assistant Secretary for Congressional, Intergovernmental and International Affairs; the Economic Regulatory Administration; DOE-ORO; and others. These activities are distributed among the various Laboratory programs and together make up about 5% of ORNL's total funding.

For the Office of Operational Safety, Transportation and Facility Safety Division, ORNL provides evaluations, reviews, technical analyses, and development support in transportation areas related to hazardous materials, including regulatory compliance evaluations and appraisals; evaluation of exemption applications; safety analysis reports; proposed regulations, standards, and orders; formulation of safety-related requirements; and preparation of supporting documentation. The program includes support for the actual performance of compliance appraisals, safety-related program evaluations, and evaluation of regulatory-related activities. Funding is expected to remain stable.

Staff from the ORNL Health Sciences Research Division (HSRD) are conducting projects involving the development or demonstration of portable techniques for detecting organic chemical components at or near hazardous waste sites. Derivative ultraviolet absorption spectroscopy using fiber-optic cables can be used to detect benzene, gasoline, and other contaminants in groundwater with a very rapid response (<1 min) using rugged, lightweight instruments. Spectrochemical techniques are expected to be equally successful in the detection of trace amounts of chlorinated hydrocarbons in soil and groundwater.

Managers at Oak Ridge sites and the Portsmouth Gaseous Diffusion Plant continue to need new or better field screening tools in the assessment of environmental restoration needs at their plants. Staff from HSRD field-test newly developed analytical techniques at these sites. In addition, they provide a rapid-response, field-portable, analytical capability to address unforeseen needs at these sites.

Biological monitoring continues to be an important activity for complying with National Pollutant Discharge Elimination System (NPDES) permits and demonstrating the efficacy of environmental restoration activities. The Environmental Sciences Division takes the lead in conducting and managing biological monitoring activities at all three Oak Ridge sites, at Portsmouth, and at the Paducah Gaseous Diffusion Plant.

In collaboration with the Human Genome Center at Lawrence Livermore National Laboratory, ORNL's Biology Division is working to establish comparative maps of mouse genomic regions that are homologous to various regions of human chromosome 19. A project currently under way aims to develop methods for isolating genes and other evolutionarily conserved sequences from cloned human DNA, in order to allow the identification of functionally significant sequences throughout the length of the human chromosome 19.

5.1.6 • Other ORNL Programs

In addition to R&D programs with direct support from a principal DOE sponsor, ORNL is engaged in a number of cross-cutting programs that support DOE's business areas and critical success factors. These include ORNL's reactor operations, scientific and technical information centers and databases, technology transfer activities and education programs, integrated R&D programs, and a group of initiatives designed to focus ORNL's resources on industrial competitiveness.

5.1.6.1 • Reactor Operations

The Research Reactors Division (RRD), which reports to the ORNL Associate Director for Reactor Operations, oversees the operation, maintenance, and support of ORNL's research reactors so that they safely, reliably, and efficiently fulfill their intended functions in isotope production, research, and training. RRD works with 11 other ORNL divisions and organizations that either conduct reactor-based research or support reactor operations. Programmatic funding support is received from DOE's Office of Energy Research (DOE-ER), and oversight is provided by the Office of Nuclear Energy (DOE-NE) and the Oak Ridge Operations Office (DOE-ORO).

ORNL management is committed to maintaining a proactive approach in operating the Laboratory's research reactors. This approach includes securing all resources necessary to ensure safe, efficient, reliable operation; the support of top management; and a continued pursuit of excellence. Total Quality Management (TQM) will continue to be emphasized, as will environmental, safety, and health requirements; Institute of Nuclear Power Operations guidance; and compliance with the regulations of DOE, the Occupational Safety and Health Administration, the Environmental Protection Agency, and the Department of Transportation.

ORNL currently operates one Category A reactor, the High Flux Isotope Reactor (HFIR). Use of HFIR is expected to continue for

- production of transplutonium isotopes,
- neutron scattering studies for materials science,
- production of high-specific-activity radioisotopes (for medicine, industry, and research),
- materials irradiation, including testing of fuel for the Advanced Neutron Source (ANS) project,
- gas-cooled reactor fuel studies, and
- neutron activation analysis.

Recognizing that excellence can only be achieved through continuous improvement, reactor operations staff regularly initiate enhanced methods, processes, and procedures. Improved relations with users are being emphasized by establishing a reputation for reliability; projecting and adhering to forward-looking, 60-day operating schedules using the HFIR Users Committee to resolve competing demands; enhancing user indoctrination and training; and monitoring user satisfaction. A strategic plan for commitment to excellence in the operation of HFIR was issued in FY 1994

Near-term and interim spent fuel disposition solutions are also receiving priority attention. Total in-pool storage is being increased to 60 spaces using the existing storage rack design in an approved array. Efforts for the near term include obtaining a shipping container to transport spent cores and further increasing in-pool storage capacity to 140 spaces using an innovative, multiple-tier storage array concept. For the interim period between in-pool storage and final disposition, development of the capability for on-site dry storage is being pursued.

The Category B Tower Shielding Reactor II was shut down in 1992. Efforts are under way to prepare for permanent shutdown; budgetary constraints and the lack of a certified shipping container for disposal of the activated reactor fuel are limiting these efforts.

Other ORNL reactors include the Oak Ridge Research Reactor (ORR), the Health Physics Research Reactor (HPRR), and the Bulk Shielding Reactor (BSR). The ORR has been defueled and shut down, and its Technical Specifications have been canceled; it has been transferred to the DOE Assistant Secretary for Environmental Management for decontamination and decommissioning. The HPRR has also been defueled and shut down, and its

Technical Specifications have been canceled; consideration is being given to transferring the reactor to Los Alamos National Laboratory. The reactor building has been retained for storage of HFIR spare parts. A shutdown plan for the BSR has been approved. The reactor has been defueled, but the fuel remains in storage racks in the reactor pool. No certified shipping container is available for disposal of the reactor pool.

One other reactor facility, the Pool Critical Assembly (PCA), is in standby status. A programmatic initiative (see Sect. 5.1.1.1) has been proposed to retain the PCA in support of training and education activities for a broad range of users, including the University of Tennessee, Louisiana State University, Mississippi State University, the Oak Ridge Institute for Science and Education, and DOE.

A second programmatic initiative (see Sect. 5.1.1.1) calls for the establishment of a Center for Excellence in Research Reactors (CERR). The CERR will help to ensure that access to irradiation facilities in nuclear reactors is readily available to meet national R&D and educational needs.

Support and involvement in the development and construction of ANS, which will ultimately replace HFIR, will be a significant mission for Reactor Operations. Several goals for Reactor Operations have been identified:

- maintaining high morale and esprit de corps;
- implementing "commitment to excellence" initiatives while reducing operating costs;
- taking leadership roles in the Association for Excellence in Reactor Operations Council and Working Groups;
- coordinating external audits, evaluations, reviews, and assessments to minimize their impact on operating and support staff;
- improving relationships with DOE-ER, DOE-NE, and DOE-ORO to an excellent state, as viewed by these sponsors, customers, and regulators;
- improving the productivity of people who are assigned to or are members of the organization;
- empowering people; and
- implementing a TQM program integrated with the existing Performance Indicators Program.

In short, the aim of the Reactor Operations organization is to earn a reputation for being DOE's best reactor management and operating (M&O) contractor.

5.1.6.2 • Scientific and Technical Information Centers and Databases

ORNL has extensive scientific and technical information resources. For example, the Laboratory is home to one of the most extensive and authoritative complexes of scientific data and information analysis centers in the United States. A complex of about two dozen information analysis centers is managed by ORNL's Environmental Sciences and Health Sciences Research divisions. More than 200 textual and/or numeric databases cover various technical disciplines, in support of DOE and other customers.

Timely communication of ORNL's scientific and technical information is a key success factor in meeting the needs of the Laboratory's DOE sponsors and in providing information to the public. ORNL plans to use its expertise and extensive investments in computing and networking technology to develop a networked information management strategy based on distributed information access. The World Wide Web (WWW) will become the

information highway of choice for global communication about ORNL's research, technology, products, and services.

As a networked laboratory, ORNL plans to use the Internet and the WWW to blend its internal and external information sources into a road map that everyone can understand and will use as a valuable resource. Information dissemination on the WWW will become a natural step in the information life cycle. Information products from ORNL's information centers and databases will be distributed via WWW servers. Subscriptions to key information will be obtained to maximize the availability of information to ORNL's staff. These plans are discussed in the ORNL Strategic Plan for Computing, which is summarized in Sect. 7.3.

ORNL's information management capabilities are widely recognized; examples of this recognition are the selection of the Laboratory as the archival repository for data from the Atmospheric Radiation Measurement (ARM) program and the designation of ORNL as a component of the World Data Center System by the U.S. National Academy of Sciences. ORNL expects to continue collaborations with NASA, the National Oceanic and Atmospheric Administration, the U.S. Environmental Protection Agency (EPA), and other organizations in meeting the technical information needs of society. These collaborations will be structured to take advantage of new technologies for information management such as the WWW.

Brief descriptions of some selected ORNL information centers and databases are presented here. Additional information on ORNL's information resource management plans is presented in Sect. 7.3.

ARM Archive • The ARM archive is storing, managing, and processing data collected during the ARM Program, part of DOE's contribution to the U.S. Global Change Research Program, and making these data available to ARM scientists and the wider science community. The ARM Program is closely integrated with the Center for Computational Sciences (CCS) and the Center for Global Environmental Studies at ORNL. The Intel Paragon supercomputers of the CCS and the massive ARM archive will be linked to allow complete, close interaction of both systems. The ARM archive in its mature state will store terabytes of data each year and will be a worldwide resource of meteorological information, not only for refining general circulation models but also for understanding atmospheric phenomena such as hail formation and downbursts.

The ARM archive staff are developing the data management software and acquiring the first increment of a mass storage system for the ARM archive. Significant progress has been made in development of the ARM archive. The initial version of the data reception system, which stores and retrieves files on the ORNL mass storage tape tower, and a prototype of the user interface, which allows users to directly request data files, are operational. Design work for the next version of the ARM archive is proceeding.

Carbon Dioxide Information Analysis Center • The Carbon Dioxide Information Analysis Center (CDIAC) is a fully integrated information analysis center that acquires or compiles, documents, archives, and distributes data and other information related to CO_2, other greenhouse gases, and climate in support of the U.S. Global Change Research Program. Extensive quality assurance audits are performed on databases that are critical to understanding global change. CDIAC supports the extensive data and information needs of the international research, policy-making, education, and corporate communities to assist them in the evaluation of complex environmental issues associated with elevated concentrations of CO_2 and other greenhouse gases in the atmosphere. CDIAC staff identify users' needs by attending workshops, reviewing literature, and maintaining personal contact. The center

obtains and evaluates data, articles, and reports for potential worldwide distribution; produces digital numeric data and computer model packages; distributes DOE reports; and produces the newsletter *CDIAC Communications* (which has a worldwide distribution of over 7500) and the *DOE Research Summary* series.

CDIAC also houses the ORNL component of the World Data Center, designated the World Data Center–A for Atmospheric Trace Gases (WDC-A). The center is a component of the World Data System, established in 1957 by the International Council of Scientific Unions to support the data needs of the geophysical community. The World Data System is a prime method of research data exchange and archiving for the international research community, with a total of 44 data centers worldwide. WDC-A was created to meet the need of the international scientific community for a system to manage critical data related to trace gas cycling and will acquire, assure the quality of, document, archive, and distribute data and information focused on the study of atmospheric trace gases, particularly those that are important to the analysis of issues for global change. Future initiatives include developing interactive data analysis systems using networked computers throughout the world.

Chemical Unit Record Estimates Data Base • To develop guidelines and limits for controlling chemical substances by a valid scientific approach, various offices within the EPA gather and evaluate information and prepare assessment reports. The Chemical Unit Record Estimates (CURE) Data Base, a comprehensive database designed and implemented by EPA's Office of Health and Environmental Assessment and ORNL, communicates this information within the agency and facilitates the chemical regulatory process.

CURE currently comprises five subfiles: a chemical dictionary, a bibliography file, an experimental data file, a central summary file, and a comment file. The chemical file lists 1900 chemicals, classified according to the structural categories developed in the EPA Genetic Toxicology Program. This unique database provides a basis for structural activity to span genetic toxicology, low-dose toxicology, and carcinogenicity. To provide technically sound and user-friendly services to a large range of EPA personnel, three disseminating vehicles are being tested at ORNL:

- CURE-PC, a stand-alone, read-only desktop version of the database that searches by chemical name, synonym, or name fragment; Chemical Abstracts Service (CAS) registry number; or document identifiers. CURE-PC includes CURESYN, a desktop resource for document preparation and other applications, and can also be used to find CAS numbers, synonyms, or EPA document information.
- CURE-Friendly, an interactive system that allows searches of the complete CURE database on the IBM mainframe computer in the EPA's Environmental Criteria and Assessment Office in Cincinnati (ECAO-CIN). It searches by target organ, cancer type, and other parameters, in addition to the search terms for CURE-PC.
- CURE Central INQUIRE, the complete CURE database on the ECAO-CIN computer. This interactive system can search for more than 250 data elements, such as chemical and document identifiers, risk estimates, and experimental data parameters.

Distributed Data Active Archive Center • In FY 1993, ORNL was designated the eighth Distributed Data Active Archive Center (DAAC) for the NASA Earth Observing System Data and Information System (EOSDIS). EOSDIS is a key component of the U.S. Global Change Research Program. The mission of the ORNL DAAC is to provide information about the earth's biogeochemical dynamics and ecology to the global change research community, policy makers, educators, and other interested persons. This information includes ground-based and remotely sensed data relating to biogeochemical dynamics; data

links are provided to other DAACs. The ORNL DAAC gathers, assures the quality of, documents, archives, and distributes data and data products from NASA's field projects. The DAAC also complements the ARM archive activity at ORNL, ensuring a close tie between the two largest single components of the Global Change Research Program.

Environmental Mutagen Information Center • The ORNL Environmental Mutagen Information Center (EMIC) collects and analyzes experimental data from papers reporting on the evaluation of chemical agents for genotoxicity. EMIC has indexed more than 78,000 papers reporting on more than 22,000 chemicals.

These data are used in the EPA's GENE-TOX database, which provides information allowing correlation of chemical structure and genetic activity, and in the EMIC database sponsored by the EPA and the National Library of Medicine. Information from these databases is incorporated into considerations for regulatory action and is included in the publications of the International Agency for Research on Cancer.

Human Genome Management Information System • The Human Genome Management Information System (HGMIS), sponsored by DOE and the National Center for Human Genome Research at the National Institutes for Health, provides assistance for much of the DNA mapping and sequencing research at ORNL and elsewhere. HGMIS is a primary information resource for DOE's Human Genome Program, in support of the DOE Office of Health and Environmental Research role in the national effort to map and sequence the human genome.

HGMIS helps to communicate genome-related issues and research to contractors, grantees, and the public, and it provides a forum for information exchange among researchers in both the DOE Human Genome Program and the international Human Genome Project. HGMIS maintains a traveling exhibit, provides administrative support to genome-related projects, and produces workshop reports and a bimonthly newsletter, the *Human Genome News*, which is distributed both in hard copy and electronically on the Internet. Also available electronically is a primer on molecular genetics prepared by HGMIS staff. A textual database of information on the human genome is being developed

Oak Ridge Environmental Information System • The Oak Ridge Environmental Information System (OREIS) is a centralized, standardized, quality-assured, and auditable environmental data management system that fulfills DOE-ORO's environmental management information obligations under an enforceable Federal Facilities Agreement (FFA) and the Tennessee Oversight Agreement to automate the centralized storage and retrieval of environmental data from the Oak Ridge reservation.

The basic mission of OREIS is efficient retrievability and long-term retention (more than 3 years) of DOE-ORO environmental data. Its primary users include DOE and its contractors and subcontractors who perform environmental restoration, compliance, and surveillance. Other users include the EPA, the Tennessee Department of Environment and Conservation, other agencies, and the public.

The objectives of OREIS are to maintain data that are complete, consistent, and fully qualified as to their usability; to provide easy access to environmental data; to facilitate the efficient access, reporting, and analysis of data; and to minimize duplication in data collection, management, analysis, and reporting as contractor and subcontractor changes occur.

The scope of OREIS includes data supporting environmental restoration, compliance, and surveillance. Types of environmental data to be incorporated in the OREIS computer system include known quality measurement and spatial data from the following environmental media: groundwater, surface water, sediment, soil, air, and biota. In addition to

environmental measurement data, the OREIS database will contain extensive descriptive and qualifier metadata to help document data quality and to enable end users to analyze the appropriateness of the data for secondary uses.

ORNL Environmental Restoration Data Management Program • The ORNL Environmental Restoration Data Management Program (ERDMP) supports compliance with state and federal regulations mandating the collection, consolidation, and use of environmental measurements information. In coordination with the OREIS development team, the site ERDMP team has developed an implementation plan for transmitting ORNL project data to OREIS based on FFA milestone criteria. This activity includes receiving and verifying data from environmental restoration projects, transfer of data to OREIS, verification, and change control interactions with environmental restoration projects and OREIS. The ERDMP team also works with the Environmental Restoration Data Quality Program to review the *Central Environmental Restoration Data Management Plan* (ES/ER/TM-88, Martin Marietta Energy Systems, Inc.) and to ensure its implementation for all site projects. These coordination efforts are essential in streamlining common data management business practices at ORNL and in maintaining the highest integrity of the data products used in programmatic decision making for environmental restoration.

The ERDMP team interacts with environmental restoration project staff to assist in the preparation and review of contract activities, the development of data management plan documentation, and readiness review tasks. In addition, the ERDMP oversees data acquisition, integration, and custodial activities for environmental restoration projects. To support project management and subcontractor staff, the ERDMP team is conducting an inventory of all environmental attribute and graphical data processed and maintained at ORNL. This resource will provide the environmental restoration data user community with specific information about the types of data available and how to obtain them for project activities. The data inventory is intended to maximize the reuse of ORNL environmental data and reduce the cost incurred by obtaining unneeded data.

Radiation Shielding Information Center • The Radiation Shielding Information Center (RSIC) is a specialized information analysis center (SIAC) authorized to collect, analyze, maintain, and distribute computer software and data sets in the areas of radiation transport and safety. RSIC follows the policy and procedure directives defined in DOE Order 1360.4B, "Scientific and Technical Computer Software," December 31, 1991, and is formally recognized by DOE as an SIAC in its area of expertise.

Established in 1962, RSIC's mission is to provide in-depth coverage of the radiation transport field to meet the needs of the international shielding community. RSIC collects, organizes, evaluates and disseminates technical information involving shielding and protection from the radiation associated with fission and fusion reactors, outer space, accelerators, weapons, medical facilities, and nuclear waste management. Specific topics include

- the physics of the interaction of radiation with matter,
- radiation production and sources,
- nuclear criticality safety,
- radiation protection and shielding,
- radiation detectors and measurements,
- shielding materials properties,
- radiation waste management,
- shields and shipping cask design,

- radiation safety and assessment, and
- atmospheric dispersion and environmental dose.

RSIC receives funding from the Nuclear Regulatory Commission, the Defense Nuclear Agency, and several DOE programs.

RSIC staff members collect, maintain, analyze, and distribute technical computing software in the areas of shielding and transport; they also provide technical consultations with requesters to resolve discrepancies, assist in installation, and answer technical inquires on radiation transport matters. RSIC also

- publishes and distributes a monthly newsletter to announce corrections, updates, or new packages as well as to notify the shielding community of items of interest,
- conducts seminars and workshops on computing methods and codes systems of particular interest to the user community,
- participates in a formal cooperative arrangement between DOE and the Nuclear Energy Agency of the Organization for Economic Cooperation and Development in the field of nuclear data and computer programs through international software exchange,
- works closely with the DOE Energy Science and Technology Software Center to avoid overlap and duplication of effort in software development and distribution,
- maintains computerized databases of abstracted shielding information selected for inclusion by technical analysts, and
- exchanges visits and guests assignments with shielding installations throughout the world to collect and share shielding technology for mutual benefit.

Remedial Action Program Information Center • The Remedial Action Program Information Center (RAPIC) serves the technical information needs of DOE's remedial action projects, including the Surplus Facilities Management Program, the Formerly Utilized Sites Remedial Action Project, and the Uranium Mill Tailings Remedial Action Project. RAPIC maintains the Nuclear Facility Decommissioning and Site Remedial Actions Data Base, a comprehensive, centralized source of information on the scientific, technological, regulatory, and socioeconomic aspects of decommissioning radioactively contaminated facilities and associated site remedial actions. The database contains 7000 records. Ten volumes of a bibliography have been published.* RAPIC also maintains the Remedial Action Contacts Data Base, which contains the names, addresses, telephone numbers, technical areas of interest, and program involvement of 1100 individuals involved in contaminated site remediation, and publishes an annual directory from this database. RAPIC staff members provide technical assistance to DOE Remedial Action Program staff and contractors on request.

Toxicology Information Response Center • The Toxicology Information Response Center (TIRC) provides information on individual chemicals, chemical classes, and a wide variety of toxicology-related topics for scientists, administrators, and the public. TIRC synthesizes comprehensive literature packages to meet specific requests. Formats include custom searches of computerized databases, manual literature searches, annotated and/or keyworded bibliographies, or written summaries of the literature. TIRC is sponsored by the National Library of Medicine.

Information Management Activities • Desktop publishing techniques have been developed for several outreach applications. A PC-based expert system, called NERC (for "NEPA Environmental Review and Compliance"), is under development for the ORNL

**Nuclear Facility Decommissioning and Site Remedial Actions,* ORNL/EIS-154, Vols. 1–10, Martin Marietta Energy Systems, Oak Ridge National Laboratory, 1980–1989.

Office of Environmental Compliance and Documentation. NERC is used in preparing documentation of compliance with NEPA requirements and other applicable federal, state, DOE, and ORNL standards for environment, safety, and health. Additional expert systems include Air Permit Regulations and Determination of RCRA/CERCLA Compliance.

5.1.6.3 • Outreach Programs

Technology Transfer Program

Energy Research Laboratory Technology Transfer Program • The Energy Research Laboratory Technology Transfer (ER-LTT) program is one of the fastest growing areas at the Laboratory. It is the primary nonprogram source of funding for cooperative R&D agreements (CRADAs) at the national laboratories overseen by the Office of Energy Research (DOE-ER). CRADAs are funded as large spin-off, multiyear projects or as small (<$100,000), one-year efforts. In addition to CRADAs, the program includes personnel exchanges, technology maturation, and technical assistance areas. These projects and the small CRADAs are supported through block funding provided to the laboratories at the beginning of the fiscal year, as discussed in Sect. 5.1.1.3.

A call for proposals for spin-off CRADA is issued once each year. Proposals are reviewed and ranked by the submitting divisions, and then by a Laboratory Selection Committee. Selected projects are submitted to the Headquarters Program Office for concurrence.

Currently, the ORNL portfolio of ER-LTT projects that are approved/executed includes 22 large spin-off CRADAs; 14 small CRADAs; 10 personnel exchanges; 7 technology maturation projects; and 3 technical assistance projects. Of these projects, 45% are with small businesses.

To encourage more technology transfer between the Laboratory and minority-owned companies, ORNL hosted 2 seminars that attracted more than 30 companies. The two-day programs featured presentations on the various technology areas as well as talks on how to work with the Laboratory. The ER-LTT Program has provided funding for small CRADAs and personnel exchanges to support this initiative.

The ER-LTT Program also initiated the first of the large, multilaboratory, broad industry cooperative partnerships with the textile industry, the American Textile Partnership (AMTEX). This effort, which is now a joint project with the Assistant Secretary for Defense Programs, involves ten DOE laboratories. R&D work focuses on five major areas: improved materials and processes; analysis, simulation, and computer integration; environmental quality and waste minimization; energy efficiency; and apparel automation. ORNL is currently involved in four tasks funded under the AMTEX initiative—the Demand Activated Manufacturing Architecture (DAMA), the Computer-Aided Fabric Evaluation (CAFE), the Textile Resource Conservation (TReC) projects, and the Rapid Cutting Projects. ORNL leads the CAFE project, which was initiated to develop advanced diagnostics instrumentation for use on high-speed weaving looms.

ORNL Technology Transfer Program • ORNL is engaged in a variety of technology transfer activities, including CRADAs with outside institutions and consortia, user agreements, exchanges of personnel between the laboratory and universities or industry, and technical assistance to industrial firms. Efforts span the range from basic research to prototyping equipment, developing products, and effecting improvements in manufacturing and processing; most of these efforts are described in the appropriate programmatic areas in this section. The ORNL technology transfer plan is summarized in Sect. 7.

The Office of Science and Technology Partnerships (Partnership Office) is the focal point for cooperative interactions between ORNL and outside groups and individuals. Established in 1989 as the Office of Guest and User Interactions to facilitate collaborative R&D and access to the Laboratory, the Partnership Office serves as the primary contact for the designated user facilities at the Laboratory, provides assistance with the entrance and approval procedures for both domestic and foreign national assignments, negotiates user agreements, provides support services for research guests, and manages all programmatic and approval processes for CRADA activity at ORNL. A major responsibility of the Partnership Office is the management of the ER-LTT Program at the Laboratory, which provides funding for many of ORNL's technology transfer activities.

Both the user program and CRADAs address the DOE mission to improve the economic competitiveness of U.S. industry by leveraging industrial and government resources to address industrial problems and by more effective use of the DOE facilities by external groups.

User Facilities • The focus for many ORNL technology transfer activities is provided by the Laboratory's user centers and programs. ORNL's designated user centers are used extensively by educational institutions and industries to carry out R&D for educational purposes and to develop new products and processes. The strong programmatic emphasis on energy efficiency and renewable energy, fossil fuels, advanced computing, environmental science, superconductivity, and defense technologies provides a firm basis for establishing cooperative working relationships with industry.

ORNL's designated user facilities and statistics on their use in FY 1993 are listed in Table A.5 in the Appendix. One of ORNL's most heavily used facilities in the past, the Holifield Heavy Ion Research Facility, is not included in these statistics because it has been undergoing modifications (see Sect. 5.1.1.1). The modified facility, renamed the Holifield Radioactive Ion Beam Facility, is also a designated user facility and is expected to begin operation in FY 1995. Of the 760 scientists who conducted experiments at ORNL user facilities in FY 1993, 102 were from industry. This is a 56% increase in the number of industrial researchers since FY 1992.

The newest facility listed in Table A.5, the Oak Ridge Centers for Manufacturing Technology (ORCMT) at the Oak Ridge Y-12 Plant, opened as a designated user facility in September 1993. ORNL researchers play an integral role in the ORCMT, which has been set up to further U.S. manufacturing capability and enhance economic competitiveness.

Of the 43 new ORNL user agreements with universities and industries signed during FY 1993, 5 were proprietary agreements. This brings the total number of user agreements signed to 239.

In August 1994, the Computational Center for Industrial Innovation (CCII) was designated a national user facility. The CCII was established in July 1994 to expand the participation of industry in the programs of the ORNL Center for Computational Sciences. Its objectives include providing U.S. industry with access to massively parallel processing and opportunities to collaborate with ORNL scientists and engineers to generate timely and innovative technical solutions to real-world problems.

Guest Research • Guest scientists are a valuable component of ORNL's research staff. Their assignments, which range from two weeks to two years, broaden the Laboratory's base of expertise and support its mission of scientific cooperation and technology transfer. The Partnership Office supported 4385 visits in FY 1993 by scientists and engineers from

universities, industry, and other federal institutions. Of this number, 1557 were industrial guests. There were 56 international institutions represented in FY 1993.

Cooperative Research • A steadily increasing number of companies recognize that a cooperative partnership with the Laboratory provides access to the significant scientific resources and skills that exist here. Furthermore, the leveraging of research dollars through cost-sharing is beneficial to both parties. At the end of FY 1993, ORNL's cumulative total for CRADAs was 94, representing commitments of $124 million split approximately half and half between federal monies and the private sector. To decrease CRADA processing time, the Partnership Office has developed and implemented more efficient procedures for Statements of Work and Joint Work Statements.

The ORNL CRADA program includes a broad spectrum of programs and technologies. Among the areas represented:

- Advanced Materials, 27%
- Advanced Computing, Modeling, and Simulation, 15%
- Advanced Manufacturing and Process Technology, 5%
- Bioscience and Biotechnology, 5%
- Advanced Energy Technologies and Conservation, 17%
- Environmental Science, 12%

AMTEX, a collaborative program involving ten DOE laboratories and the U.S. integrated textile industry, is engaging the technical capabilities of the laboratories in developing and deploying technologies that will increase the competitiveness of this industry. ORNL is currently involved in four AMTEX CRADAs. The Clean Car and Partnership for a New Generation of Vehicles initiatives are expected to present extensive opportunities for cooperative research during the planning period. ORNL is also pursuing cooperative research opportunities through the Technology Reinvestment Project sponsored by the Advanced Research Projects Agency and through the Applied Technology Program sponsored by the National Science Foundation.

Long-Range Plans • Long-range plans for user facilities include the development of new centers as appropriate to support ORNL's mission (see Sect. 3). The Neutron Residual Stress Center, a partnership between DOE-ER and the Assistant Secretary for Energy Efficiency and Renewable Energy (DOE-EE), will be fully operational in late FY 1995 or early FY 1996. This facility is already being used to quantify stress in joined materials, a major problem for manufacturers of metal parts, ceramic-metal components, laminates, composites, or thin-film coatings. It will provide the capability to quickly measure strain fields within metal or ceramic components with masses of several kilograms.

The Advanced Neutron Source (ANS), described in Sect. 4.1, will be the nation's state-of-the-art research reactor. Reactor startup is scheduled for FY 2003, and ORNL expects ANS to be designated a user facility. More than 1000 scientists and engineers per year are expected to use one of the more than 30 instruments that the ANS will provide for experiments on materials and basic nuclear science.

ORNL will also pursue new opportunities for technological and scientific exchange with universities, industry, other DOE laboratories, and other federal agencies. To facilitate these efforts, the ORNL Technology Transfer Office has established a point of contact with each ORNL division to coordinate activities such as calls for proposals and CRADA proposal reviews.

Education Programs

In February 1994, ORNL's Office of Science Education and External Relations (SEER) became part of a new directorate for Computing, Networking, Informatics, and Education. Creation of this directorate indicates ORNL's increasing focus on education as a major part of the Laboratory's mission. Education programs include innovative precollege educational activities for both students and teachers and activities designed to increase the involvement of university personnel in ORNL's R&D activities. Table A.6 in the Appendix lists these activities and the number of participants.

SEER has defined its mission, vision, and overarching goals as follows.

Mission • Use Martin Marietta Energy Systems, Inc., ORNL, local, state, regional, and national resources to be a world-class Regional Science Education Center especially for the southeastern United States, with strong supporting constituencies at education and research institutions.

Vision • Become the benchmark for the premier and most comprehensive science education program in the Department of Energy family of laboratories and contractors.

Overarching Goals • Build educational, training, and research partnerships that serve to

1. enhance the capability, quality, and diversity of the nation's scientific and technical workforce,
2. strengthen ORNL's and Energy Systems' technical capabilities, supporting constituencies, scientific and technical staff, and contributions,
3. maintain and further develop education as a primary mission of the Laboratory consistent with Public Law 101-510 (Department of Energy Science Education Enhancement Act 42 U.S.C. 7381), and Executive Order 12821 (Improving Mathematics and Science Education in Support of the National Goals), November 16, 1992,
4. support National Education Goal 5: "By the year 2000, U.S. students will be the first in the world in science and mathematics achievement," and
5. contribute our collective education resources to the success of national science and technology initiatives, including those in mathematics and science education, high-performance computing and communications, biotechnology research, advanced manufacturing R&D, U.S. Global Change Research Program, and emerging opportunities such as computational biology.

Highlights • Partnerships strengthen the focus on the national education goals and on education reform in the southeastern United States. These partnerships include cooperative efforts with other agencies; state and regional schools, colleges, and universities; and the private sector, with a major focus on computing and communications technology for educational applications. ORNL's educational initiatives include

- the Ecological and Physical Sciences Study Center, which has served over 100,000 participants since it began 10 years ago;
- sponsorship of summer mathematics and science camps for middle-school-age youth (especially young women) in the area and throughout the southeastern United States;
- cosponsorship of regional science bowls in Alabama, Mississippi, and Tennessee to qualify teams for the DOE-sponsored National Science Bowl;
- the Saturday Academy of Computing and Mathematics, which draws on volunteers from the ORNL technical staff as mentors for area secondary students;

- the Oak Ridge Educational Network, which gives students and teachers access to high-performance computing capabilities, networking, and communications;
- the Adventures in Supercomputing program, which gives students and teachers in over 50 high schools access to supercomputers, equipment, training, and technical support;
- an annual "Women in Science and Technology" conference for high school and college students;
- classroom teaching and enrichment resources such as "The New Explorers," a DOE-sponsored public television series; and
- a multistate regional Summer Science Honors Academy sponsored by the Appalachian Regional Commission as a companion to the DOE High School Science Student Honors Program in Environmental Sciences.

School, college, and university guests are hosted by the Laboratory through a variety of mechanisms:

- R&D subcontracts;
- short-term research in the designated DOE user facilities and other resources;
- supervision of students and collaborations with faculty through research participation appointments;
- visits of technical personnel and equipment loans;
- close collaborations with universities and university consortia, appointments of teachers as research associates, and professional development workshops and student enrichment experiences; and
- learning experiences through the Ecological and Physical Sciences Study Center.

More than 35 programs—undergraduate, graduate, postgraduate, and faculty—enable students and faculty to participate in ORNL research. About half of these summer and/or academic-year appointments are administered jointly with the Science/Engineering Education Division of the Oak Ridge Institute for Science and Education.

DOE and ORNL benefit directly from the mission support gained, especially through university-level participation programs. These partnerships represent a mutually beneficial and highly cost-effective way to support ORNL's programmatic goals, while providing education and training. Students have made substantive contributions to highly successful ORNL projects. Collaborations with college and university personnel also help to fulfill the Laboratory's technology transfer objectives.

5.1.6.4 • Integrated R&D Programs

ORNL carries out a number of cross-cutting programs that serve multiple customers within and outside DOE. These programs integrate resources from across the Laboratory and increasingly from other DOE facilities in Oak Ridge.

Robotics and Intelligent Systems Program

The Robotics and Intelligent Systems Program (RISP) serves as the focal point at ORNL for R&D in remote systems, robotics, teleoperation, and related aspects of intelligent machines. The program is interdisciplinary in nature and uses the expertise of scientists and engineers from several research and support divisions of ORNL. RISP conducts research for DOE, the Department of Defense (DOD), and other sponsors.

RISP addresses R&D goals for extending human senses and dexterity into unstructured hostile environments and for automation of routine, repetitive, and/or physically

demanding tasks. The research includes developing an appropriate combination of teleoperation and autonomous operation in systems to achieve the necessary level of task performance while maintaining robust human-machine interaction. The programs cover activities in basic R&D as well as development and full-scale demonstrations of system prototypes, including remote operations and maintenance.

RISP performs R&D for several major DOE programs. Research into intelligent machines is performed for the Office of Basic Energy Sciences Engineering Research Program. For the Office of Fusion Energy, RISP performs remote equipment design and remote mock-up demonstrations for the Tokamak Physics Experiment and remote system planning and development support for the International Thermonuclear Experimental Reactor. Efforts for the Assistant Secretary for Environmental Management involve national planning and technology development and demonstration of robotics technology for support of national restoration efforts. Key areas of focus for ORNL include underground storage tanks, buried waste retrieval, contaminant analysis automation, mixed waste operations, cross-cutting and advanced technologies, and decontamination and decommissioning. RISP also provides technical support to national integrated demonstrations, to ongoing environmental restoration projects on the Oak Ridge reservation, and to the AMTEX program, which applies the resources of the national laboratories to the problems of the American textile industry (see Sect. 5.1.6.3).

Under the auspices of the U.S. Army Human Engineering Laboratory, RISP personnel are contributing to the Robotics Test Bed Program, an element of the Office of the Secretary of Defense Unmanned Ground Vehicles Master Plan Program, which is assessing opportunities for new robotic combat functions. A number of programs are being performed under the sponsorship of the U.S. Army Program Manager Office for Ammunition Logistics and the Program Manager for Future Armored Resupply Vehicle. These programs include the development of vehicles to rapidly rearm battle tanks and self-propelled artillery pieces, systems to process ammunition rounds before loading them onto the rearm vehicles, and paperless accounting systems based on high-density, machine-readable symbologies. RISP personnel also contribute to the development of autonomous vehicles for aircraft carrier deck support functions under the sponsorship of the Naval Air Warfare Center.

RISP builds on ORNL strengths in remote technology, teleoperations, robotics, and autonomous machine research. Program activities that cut across the full spectrum of related technologies are under way for DOE, DOD, and other sponsors. Because research for these agencies often employs similar technologies, significant cost savings can be realized through integration of resources at the working level. Significant new efforts are in progress to support initiatives in national competitiveness. CRADAs have been established in a number of areas, and industrial partnership contacts have been established in others. Initiatives to provide additional support for competitiveness activities are being actively developed; one of these, the Center for Robotics and Intelligent Systems, is described in Sect. 5.1.6.5.

Programs at the High Temperature Materials Laboratory

The High Temperature Materials Laboratory (HTML), described in detail in Sect. 5.1.2.1, is one of ORNL's national user facilities. Research at HTML is conducted in seven user centers.

One of the newest of these centers at the HTML is the Ceramic Manufacturability Center, a partnership between DOE's Office of Energy Research (DOE-ER), the Assistant

Secretary for Energy Efficiency and Renewable Energy (DOE-EE), and the Assistant Secretary for Defense Programs that achieved operational status in FY 1994. It focuses on machining research and surface topography characterization techniques.

The Neutron Residual Stress Facility, a partnership between DOE-ER and DOE-EE, involves special neutron diffraction instrumentation at the High Flux Isotope Reactor and is scheduled for full operation in early FY 1996. This facility will provide the first capability in the United States for quickly measuring the strain fields within large (up to several kilograms) metal or ceramic components. It has already attracted industrial users from such companies as Alcoa, General Motors, and General Electric.

Oak Ridge Centers for Manufacturing Technology

Manufacturing is a major source of high-paying and highly skilled jobs that plays a central role in the national economy. The Oak Ridge Centers for Manufacturing Technology (ORCMT), a joint initiative of ORNL and the Oak Ridge Y-12 Plant, is a national industrial resource for applied research, development, deployment, prototyping, and education. The combination of ORNL's excellence in scientific R&D and Y-12's premier manufacturing capability is unmatched anywhere in the world. The ORCMT was established to draw on the materials development, characterization, and processing expertise and the manufacturing and fabrication capabilities of Oak Ridge to improve American industrial competitiveness.

Over 20 centers organized under 7 core technology areas are in place and providing results (see Table 5.12). ORNL contributions to ORCMT include three especially significant areas: modeling, mechanics, and design; materials processing and applications development; and intelligent measurement systems.

Strategic alliances with the National Institute of Standards and Technology of the Department of Commerce, southeastern state economic development organizations, educational institutions, industrial societies, and industry consortia allow the ORCMT to complement existing activities. In FY 1993, ORCMT stimulated over $53 million of private-sector impact in 46 states, strongly emphasizing the southeastern United States (a 350% return on investment for the use of federal funds). An initiative for stabilizing and enhancing the ORCMT is presented in Sect. 5.1.6.5.

Oak Ridge Center for Healthcare Industry Development

The goal of the Oak Ridge Center for Healthcare Industry Development (ORCHID), established in 1994, is to provide an integrated resource to assist the healthcare industry in lowering costs while maintaining quality. The goal will be attained through facilitated collaborations among the Oak Ridge complex, healthcare providers, academia, and industries. ORCHID is integrated into the ORNL Center for Biotechnology, described in Sect. 5.1.1.1.

The unique resources in Oak Ridge include a wide range of capabilities that are of interest to the healthcare industry. ORCHID provides a mechanism for combining ORNL's expertise in biomedical research, high-performance computing, instrumentation, robotics, and sensors; the manufacturing, system integration, and prototype development capabilities of the Oak Ridge Y-12 Plant; the software development and telecommunications talents in the Martin Marietta Energy Systems, Inc., Data Systems Research and Development organization, and the resources of other central organizations. The Oak Ridge record of successful collaborations with private industry has attracted a number of private industry participants who are interested in biomedical projects.

Table 5.12
Core technology areas and centers at the Oak Ridge Centers for Manufacturing Technology

Manufacturing Technology Deployment	**Energy and Environmentally Conscious Manufacturing**
Manufacturing Skills Campus	Energy Conservation Center
Skills Demonstration Center	Pollution Prevention Center
Direct Assistance Program	Alternate Refrigerants Center
Manufacturing Information Resources Center	
Manufacturing Technology Demonstration	**Manufacturing Quality and Process Assurance**
Concurrent Engineering Center	Metrology Center
Ultraprecision Manufacturing Technology Center	Measurement and Control Technology Applications
Micro Manufacturing Technology Center	Diagnostics and Quality Assurance Center
Thin Film Technology Center	Testing and Evaluation Center
Manufacturing Prototyping and Demonstration Center	Advanced Photonics
Manufacturing Technology Development	**Industry-Specific Technology**
Materials Joining Center	Machine Technology Access Center
Composites Manufacturing Technology Center	Advanced Ceramic Technology Center
Materials Forming and Processing Center	Advanced Propulsion Technology Center
Plating and Cleaning Center	Ceramic Electronic Packaging
Coatings and Finishings Center	**Special Materials Processing**
Medical Health Engineering and Manufacturing Center	(under development)

A window of opportunity exists for Oak Ridge to be at the forefront of a major healthcare initiative. Comparisons with other DOE facilities have proven that no other single site has the breadth of resources available in Oak Ridge.

Center for Environmental Technology

The Center for Environmental Technology (CET) was established in 1993 as a regional and national center to integrate environmental technology activities for the Oak Ridge complex, provide a focus on market-driven technology programs, and accelerate the commercialization of environmental technology innovation. ORNL, the Martin Marietta Energy Systems, Inc., Environmental Restoration and Waste Management Organization based at the Oak Ridge K-25 Site, and the Oak Ridge Y-12 Plant are partners in CET, which uses the new approach to environmental management: leveraging DOE funds to achieve cost-effective environmental solutions. The total volume of revenues under CET management currently exceeds $230 million.

CET users can draw on the specialized resources of the Oak Ridge complex; these resources include scientists, engineers, technicians, and regulatory experts as well as world-

class laboratories and unique user facilities for full-scale demonstrations. The CET's mission is to

- deliver proven and accepted environmental restoration and waste management technologies to the market at an accelerated rate;
- provide user-friendly facilities that actively support private sector involvement on site;
- make environmental restoration and waste management projects at the Oak Ridge Complex a national showcase for technologies by serving regional needs while drawing on national resources;
- provide environmental products, services, and management expertise to federal, state, and local agencies; and
- educate, train, and retrain personnel to ensure the availability of an environmental work force by the year 2000.

CET accomplishes its mission by assisting the private sector in demonstrating its technology at DOE sites and by facilitating technology transfer from DOE to the private sector.

CET is organized into five divisions, with a senior advisory group that serves as an expert reference for CET, screening promising new or ongoing environmental technologies for originality, potential for success, and commercial viability. This group also functions to provide peer review support, stimulate innovation, explain risk-based decision processes, and respond to emergency needs.

The Hazardous Waste Remedial Action Program develops, promotes, and applies cost-effective hazardous waste management and environmental technologies to help resolve national problems and concerns. It applies the unique combination of R&D capabilities, technologies, expertise, and facilities in the Oak Ridge complex to address problems of national importance.

The Office of Environmental Technology Development, which is part of the ORNL Energy and Environmental Technologies directorate, provides research, development, and technology demonstration support to CET. This support is provided through environmental restoration technology, waste management technology, technology development support, site demonstration coordination, and science and technology support.

The primary purpose of the Office of Technology Alliances is to stimulate the formation and creation of business relationships with the private sector and government partners. This office enhances and expedites the transfer of environmental technologies both into and out of the DOE complex and is the focal point for initial contacts from external customers.

The National Institute of Environmental Renewal is a regional institute for the development, testing, demonstration, and evaluation of environmental technologies and systems. A partnership has been formed between Martin Marietta Energy Systems, Inc., and the Lackawanna Heritage Valley Authority through a cooperative R&D agreement that draws on the resources and capabilities of both partners. Energy Systems, through CET, provides program management, technology transfer, and technical expertise specific to the environmental area. The Commonwealth of Pennsylvania provides access to industrial sites and the private sector as well as unique capabilities in education and training.

The Office of Environmental Technology Assessment serves CET's needs in risk analysis and risk-based decision processes, evaluation of public policy and potential acceptance, regulatory legislation, potential socioeconomic impacts, cost analysis, and commercial viability. This office will facilitate a unique cross-fertilization with technology users and developers from the private sector, DOE, and other government agencies by supporting the

deployment of cost-effective, innovative, safe, and commercially viable technologies that will decrease the cost of environmental restoration and waste management.

An initiative for broadening ORNL's environmental technology activities, building on the capabilities of CET and other organizations in the Oak Ridge complex, is presented in Sect. 5.1.6.5.

Center for Risk Management

ORNL's Center for Risk Management, established in 1991, is an interdisciplinary R&D organization that addresses risks to human health and the environment that are associated with hazardous waste and energy production and consumption. Areas of interest include environmental restoration and other health and environmental problems—including radionuclides and toxic chemicals, acid deposition and climate changes, and policy and management mechanisms to reduce the adverse effects of these problems. Center staff draw on ORNL's diverse capabilities in health sciences, biology, environmental sciences, social sciences, and engineering to address these issues. Activities include environmental fate/transport modeling, human and environmental toxicology, epidemiology, applied ecology, environmental monitoring, database development, and risk/benefit and policy analyses.

Integrated Assessments

Integrated assessment is a process in which the scientific, technical, social, environmental, and economic consequences of alternatives are evaluated to provide the information and analyses needed by policy makers and other decision makers to arrive at informed decisions on science and technology. For any problem, the integrated assessment process should identify the policy alternatives; conduct quantitative and/or qualitative analysis of the scientific, technical, social, environmental, and economic costs and benefits of each alternative; identify the major sources of uncertainty; and provide some measure of the consequences of a wrong decision.

ORNL has a unique breadth of scientific, engineering, environmental, economic, and social science expertise to address the broad range of issues that arise in performing an integrated assessment. More importantly, ORNL has extensive experience in using multidisciplinary teams to perform integrated assessments to address a wide range of issues. ORNL has 22 years of experience with integrated assessments performed in support of the National Environmental Policy Act and covering a wide range of actions for diverse issues, from the generic relicensing of all commercial nuclear power plants in the United States to evaluating the safety, environmental, and health initiatives supporting U.S. research operations in Antarctica.

ORNL provides planning support to several parts of DOE by providing assessments and analyses of research opportunities. Other examples of ORNL's integrated assessment capabilities include support for the design of the Advanced Neutron Source and vertical integration of research results into assessment and policy analysis under the National Acid Precipitation Assessment Program.

Ongoing and future work in this area of activity includes scientific method development in support of the Environmental Protection Agency's Environmental Monitoring and Assessment Program (EMAP). EMAP's goal is to monitor and assess the condition of the nation's ecological resources to contribute to decisions on environmental protection and management. ORNL will continue to play a key role in scientific method development as

EMAP's integrated assessment activities are developed over the next two years. In addition, the recent fuel cycle externalities study headed by ORNL and conduced jointly with the European Communities defined a framework for quantifying social costs and benefits not reflected in the price of the product associated with the production and consumption of energy from different fuel sources. ORNL's current projects on decision-making systems related to integrated assessment include studies of investment behavior to better understand the process of rational choice in the face of uncertainty, postponement of decisions while gathering information, the design of pollution trading mechanisms to provide incentives for voluntary behavior by decision-making agents pursuing their own self-interest, and examining the implications of chlorofluorocarbon (CFC) substitutes on global climate change.

In the context of global climate change, ORNL is helping to focus the national integrated assessment programs by organizing and conducting a series of national and regional workshop that will identify national policy issues and the available frameworks and methodologies to address these issues. Approaches for regional ecological integrated assessments are also being developed through a separate series of workshops. Funding in this area is expected to grow from $70 million in FY 1995 to $80 million by FY 2000.

5.1.6.5 • Industrial Competitiveness Initiatives

In its strategic plan (see Sect. 3), ORNL has selected industrial competitiveness as one of its mission areas, reflecting DOE's commitment to assisting U.S. economic competitiveness as well as the Laboratory's long-term involvement with spinning off technology to the private sector.

One important and successful mechanism for transferring knowledge and technology to industry is the user center. These centers offer a means of focusing the core competencies of the Laboratory on the needs of industry.

User centers provide a coordinated and professional guide for industry access to the Laboratory and, through industry advisory boards and industrial customers, provide an explicit mechanism for industry input to the Laboratory and DOE. Centers can present "one-stop shopping" for a range of capabilities essential for commercialization of technology. Centers that can mature technology to a point close to commercialization reduce development cost and shorten the time it takes to bring new product and processes to market. Centers also support education, preserve the capability to meet the objectives of the other Department missions, and help establish DOE as the science and technology agency of choice. Centers can involve multiple laboratories and in doing so provide a structure for the "virtual laboratory" envisioned by DOE.

Finally, from the perspective of industry, centers improve access, especially for small and medium-size businesses, to the capabilities of the Laboratory for regional and national programs. ORNL has a unique advantage among DOE laboratories because of its proximity to the unique manufacturing and environmental capabilities of other DOE facilities.

Table 5.13 shows ORNL's core competencies, some of the existing resources that extend these core competencies to users, and some proposed resources that would strengthen ORNL's contribution to DOE's industrial competitiveness mission. Owing to the multidisciplinary nature of ORNL's research programs, several centers support more than one core competency; the High Temperature Materials Laboratory, which supports basic and applied R&D and industrial collaborations, is a good example. There is a clear need for coordination

Table 5.13
ORNL core competencies and resources (existing and new or proposed) for extending these core competencies to industry

ORNL core competencies	Resources	
	Existing	New/proposed
Established		
Advanced materials synthesis, characterization, and processing	High Flux Isotope Reactor, High Temperature Materials Laboratory, Neutron Scattering Research Facilities, Shared Research Equipment Program, Surface Modification and Characterization Laboratory	Advanced Materials Science and Engineering Complex, Holifield Radioactive Ion Beam Facility
Biological and environmental science and technology	Bioprocessing Research and Development Center, Center for Environmental Technology, Oak Ridge National Environmental Research Park	Center for Biological Sciences, Environmental Technology Collaboration, Oak Ridge Centers for Healthcare Industry Development
Energy production and end-use technologies	Bioprocessing Research and Development Center, High Flux Isotope Reactor, High Temperature Materials Laboratory	Buildings Technology Center
Neutron-based science and technology	High Flux Isotope Reactor, Neutron Scattering Research Facilities, Oak Ridge Electron Linear Accelerator, Radiochemical Engineering Development Center	Advanced Neutron Source, Holifield Radioactive Ion Beam Facility
Emerging		
Computational science and advanced computing	Center for Computational Science	Computational Center for Industrial Innovation
Manufacturing technologies (shared with the Oak Ridge Y-12 Plant)	Center for Environmental Technology, Oak Ridge Centers for Manufacturing Technology (ORCMT), Robotics and Intelligent Systems Program	Center for Robotics and Intelligent Systems, increased support for ORCMT, Intelligent Measurement Systems Laboratory
Institutional		
Development and operation of national research facilities	Designated user facilities plus many others	All new and proposed user centers
Integrated R&D and partnerships	Science and Technology Partnerships Office, designated user facilities plus many others	All new and proposed user centers
Technology transfer	Office of Technology Transfer, Science and Technology Partnerships Office	All new and proposed user centers
Science education	Adventures in Supercomputing, Oak Ridge Educational Network, Office of Science Education and External Relations, designated user facilities plus many others	Computational Science Education Project, all new and proposed user centers

and integration of the efforts of the cross-cutting centers around new programmatic opportunities. Additionally, advantage will be taken of the full extent of the capabilities of DOE's Oak Ridge facilities through integration and/or collaboration.

The following descriptions of initiatives for the Oak Ridge Centers for Manufacturing Technology, collaboration among all of the environmental activities in Oak Ridge, the Intelligent Measurement Systems Laboratory, and the Center for Robotics and Intelligent Systems represent a way of integrating and applying the capabilities of ORNL and the Oak Ridge complex to DOE's needs. Although several of these initiatives include recommendations for increased funding, it is essential to recognize that the integration and collaboration (within Oak Ridge and with other DOE laboratories and facilities) and establishment of user capability for these initiatives can start now.

Initiative

Oak Ridge Centers for Manufacturing Technology

The Oak Ridge Centers for Manufacturing Technology (ORCMT) are described in Sect. 5.1.6.4. Long-term base funding is needed to stabilize and enhance this groundbreaking, nationally recognized effort. Funding from multiple sources—including industrial partners, contracted work, and DOE core initiatives—will be developed to match and expand the program so that base funding will constitute about 40% of the program in three years.

In support of ORCMT, ORNL requests

- Designation of ORCMT as a National Manufacturing Complex with a charter to perform R&D for manufacturing technologies and to build test prototype products and process lines. This facility could be a joint DOE/Department of Commerce facility dedicated to manufacturing and to forging a stronger interagency partnership.
- Base funding of $25 million for ORNL's participation in ORCMT, beginning in FY 1995, to supplement the $50 million provided by DOE's Assistant Secretary for Defense Programs (see Table 5.14). Increased funding in future years should be based on results, measured against DOE's industrial competitiveness goals.

Table 5.14
ORNL base funding projections by fiscal year for the Oak Ridge Centers for Manufacturing Technology
($ in millions)

	1995	1996	1997	1998	1999
Operating expense	25.0	25.0[a]	25.0[a]	25.0[a]	25.0[a]
Capital expense	2.5	2.5	3.0	4.0	5.0

[a]Growth if warranted by results.

Initiative

Environmental Technology Collaboration

Oak Ridge has a broad range of environmental technology capabilities that include basic research, environmentally friendly manufacturing and processing, and environmental restoration and waste management. One of the focus areas of the Oak Ridge Centers for Manufacturing Technology is to team with American industry to develop, demonstrate, and deploy cost-effective, innovative, safe, and economically viable environmental technologies. The Center for Environmental Technology has been established to integrate related activities within the Oak Ridge complex, to provide a focus on market-driven technology programs, and to accelerate the commercialization of environmental innovation. The Center for Waste Management provides an avenue to the private sector, academia, and government to help meet the waste management opportunities and challenges faced in Oak Ridge.

In 1995, the Environmental Technology Collaboration will continue to forge strong links among these organizations and ORNL to provide a full range of capabilities in support of industrially grown environmental technology. Special emphasis is placed on establishing cooperative arrangements with industry, universities, and other federally funded R&D centers. The collaborating organizations can develop and demonstrate a full range of environmental technology products and services, and they can support deployment to industry and to government.

The goal of this initiative is to make pollution and control, environmental remediation, and waste management technologies at the Oak Ridge complex a regional and national showcase for assisting industry while providing much-needed solutions to problems important to the DOE. The major action for 1995 is to more fully integrate the full spectrum of Oak Ridge environmental technologies in a collaborative fashion and, where appropriate, to produce integrated strategies and operating plans. Attention will be given to broadening the use of the user facility concept throughout this initiative.

Activities are funded by DOE, other federal agencies, and the private sector. The Assistant Secretary for Defense Programs and the Assistant Secretary for Environmental Management fund much of the environmental technology work currently being performed at DOE's Oak Ridge facilities. An initial estimate of the additional funding needed to maximize the effectiveness of ORNL's environmental technology transfer and team-building with industry and other government agencies is shown in Table 5.15.

Table 5.15
Incremental budget projections by fiscal year for the Environmental Technology Collaboration
($ in millions)

	1995	1996	1997	1998	1999	2000
Operating	15.0	16.5	18.0	20.0	22.0	22.0
Capital	0.0	1.5	2.0	2.5	2.5	3.0

Initiative

Intelligent Measurement Systems Laboratory

ORNL proposes to establish an Intelligent Measurement Systems Laboratory (IMSL). As a user facility, the IMSL will provide design, simulation, prototyping, testing and system integration facilities, and technical resources requested by industry, universities, DOE, and other federal agencies. An industrial advisory board will keep the IMSL focused on the R&D needed for higher intelligence in measurement systems. According to the industry, these more intelligent systems will enhance the global competitiveness of U.S. industries, provide new manufacturing jobs for American workers, and further American education in measurement science.

The instrument industry is beginning to use silicon-based sensors to replace electromechanical sensing elements. These sensors transmit digital information instead of the analog data that have always been a sensor's output. At present, 99% of the sensors in the field still have analog output, but this will change quickly. When sensors send digital output, they are easier to connect to a wide range of computer data acquisition and data processing products. The data acquisition and processing allows the systems to incorporate computer algorithms and "if-then" rules, contain self-checking and self-calibrating, and autonomously make decisions based on several measured parameters. These features may be thought of as "intelligence." As the technology advances, the capabilities of the features will increase, resulting in more intelligent systems.

Like the High Temperature Materials Laboratory, the IMSL will provide facilities and staff to industry and universities at no charge for nonproprietary R&D. Universities will provide graduate students, postdoctoral researchers, and collaborating professors. Industry will provide proposed projects and, sometimes, assigned personnel. Proprietary work proposed by industry that is aligned with the base R&D program will be performed at the expense of the industrial participant.

This initiative will benefit many industries, beginning with the instrument and measurement industry. According to U.S. Department of Commerce statistics, this area of the economy is large and diverse. In 1990, more than 10,000 U.S. companies, representing 949,000 employees, shipped almost $124 billion worth of instruments and related products. Most of these companies are small and have few or no R&D capabilities. Making this industry more competitive with international vendors will help to improve the balance of trade and provide more jobs for U.S. workers.

Beyond this market, almost all major segments of the economy depend on measurements. As the instrument and measurement industry provides higher accuracy and more functionality, there will be considerable benefits to the United States.

A critical requirement for enhancing U.S. manufacturing and process industry competitiveness is developing or improving affordable in-process measurement technology. Japanese businesses have repeatedly demonstrated enhanced quality and reduced cost of manufacturing goods through the intensive application of in-process measurement science technologies. (In a 1987 study, DOE concluded that savings of over $10 billion in energy costs could be realized in U.S. industry through improved sensor technology.) The IMSL will assist these industries in the assessment and use of intelligent measurement systems to provide efficiency, environmental compliance, and optimum control.

Other industries will also benefit. The healthcare industry needs better measurement technology to decrease diagnostic costs and improve surgical support. The automotive industry needs better measurement technology to improve fuel efficiency and reduce pollution. The agribusiness industry needs better measurement technology for precision farming.

A measure of the value of the IMSL will be the amount of industry support that it attracts and maintains. We estimate that approximately 50 users per year will have agreements in place with IMSL within 5 years. Budget projections are shown in Table 5.16.

ORNL's Instrumentation and Controls Division provides a strong nucleus for a measurement science center. ORNL's research divisions will combine to provide a formidable interdisciplinary team that can address almost any sensor and measurement science problem or task. Strong synergy will exist between the IMSL and the Oak Ridge Centers for Manufacturing Technology.

Table 5.16
Budget projections by fiscal year for the Intelligent Measurement Systems Laboratory
($ in millions)

	1995	1996	1997	1998	1999	2000
DOE funding	2.2	3.0	5.5	7.5	10.5	15.0
Funding from other Federal agencies	0.0	0.5	1.0	2.0	4.0	7.0
Total federal funding	2.2	3.5	6.5	9.5	14.5	22.0
Industry funding	0.5	1.0	2.0	2.5	5.0	6.0
Distribution of funds						
Operating expense	1.7	4.0	7.5	10.0	12.5	16.0
Capital equipment	0.5	1.0	1.0	1.5	5.0	4.0
Construction	0.0	0.0	0.0	1.0	2.0	8.0

Initiative

Center for Robotics and Intelligent Systems

The Center for Robotics and Intelligent Systems will enhance the transfer of new developments in robotics technology to the private sector. It will draw on the existing resources (staff, equipment, and facilities) of the ORNL Center for Engineering Systems Advanced Research, the Robotics and Process Systems Division, and the Engineering Physics and Mathematics Division, with technical support from the Instrumentation and Controls Division, the Plant and Equipment Division, and the Energy Systems engineering organization. The center will be available to private industry, the robotics R&D and user communities, and other applied R&D programs.

Robotics research and technology development at the Center will span the range from basic remote operations through telerobotics to sensor-based intelligent robots for unstructured environments. The Center will include related technologies such as sensors, controls, dexterous manipulation systems, mobile platforms, human-machine interface, simulation and visualization, and high-performance computing environments.

It will support national competitiveness initiatives by making government-sponsored robotics technology and facilities accessible to the private sector, stimulating R&D partnerships with industry, and accelerating the use of emerging robotics technology.

5.2 • Work for Others

Work undertaken for federal agencies other than DOE, nonfederal agencies, private organizations, and the Nuclear Regulatory Commission accounts for about 15% of the Laboratory's total budget. The level of funding for work for others (WFO) is expected to remain relatively stable over the next several years until the Federal budget stabilizes. However, the distribution of work for non-DOE sponsors is changing, moving from an emphasis on Department of Defense support to other agencies as the defense budget declines. An increasing amount of the WFO work is expected to involve support from private industry in terms of technology transfer or Laboratory-industry partnerships.

Much of the existing WFO effort at ORNL consists of relatively small (<$500,000) projects. This emphasis on small projects tends to dilute the efforts of staff and to consume a disproportionate amount of support staff. Increasing the number of large (>$5 million) projects would allow for more efficient use of staff and resources.

The goal over the next several years is to transform the current program into a more balanced split between large and small projects. Achieving this goal may require broader collaboration with other parts of the Oak Ridge complex as well as other national laboratories. In FY 1994, we initiated a collaborative effort with the Energy Systems Office of Technology Transfer, the Hazardous Waste Remedial Action Project, the Data Systems Research and Development organization, the National Security Program, and several other R&D programs to explore new ways of effectively responding to new opportunities that might involve WFO.

ORNL staff are also participating in the Added Factor/Waiver Policy Task Team chartered by DOE's Work for Others Working Group. This team is focusing its efforts on reexamining the added factor waiver criteria and procedures and on developing proposals for changing current policy.

5.2.1 • Federal Organizations

5.2.1.1 • Nuclear Regulatory Commission

Current ORNL efforts for the Nuclear Regulatory Commission (NRC) reflect the NRC's priorities: response to public attitudes requiring a high degree of confidence in the safety of nuclear power, the maturing of the current generation of U.S. nuclear reactors, and certification of the next generation of reactors. Completion of the more than 100 nuclear plants ordered in the 1960s and 1970s, coupled with the upcoming expirations of operating licenses for many of these plants, has shifted the emphasis of NRC research toward structural and component safety issues, structural aging research, analysis of reactor operational data, advanced instrumentation and diagnostics, accident sequence analysis, and license extension requirements. The NRC is also working to certify five advanced light-water reactor (LWR) designs. ORNL funding from the NRC is expected to remain fairly stable over the next several years.

ORNL performs work primarily for four offices within NRC: the Office of Nuclear Regulatory Research (RES), the Office for Analysis and Evaluation of Operational Data (AEOD), the Office of Nuclear Reactor Regulation (NRR), and the Office of Nuclear Material Safety and Safeguards (NMSS). RES, the major sponsor of ORNL activities, conducts comprehensive research programs that lead to regulatory guidelines and standards issued by the NRC. NRR is charged with implementing regulations dealing with licensing and inspection of the commercial nuclear power industry; these regulations draw heavily on knowledge obtained from research programs. AEOD collects, analyzes, and evaluates operational safety data to identify areas requiring NRC or industry action. NMSS is charged with overseeing public health and safety licensing activities in the nonreactor nuclear arena.

Nuclear Regulatory Research

During the planning period, the NRC will continue to give priority to investigating long-term behavior of reactor pressure vessels, severe accident issues, instrumentation and controls technology, and issues relating to extension of the operating licenses of existing power plants beyond their original 40-year period. ORNL is developing a structural aging handbook and a materials property database for aging concrete structures in U.S. nuclear power plants.

Continuing research on fission product behavior for LWRs under severe accident conditions is helping to resolve regulatory issues in this area. This work provided a basis for modifications of the portions of NRC Regulatory Guides 1.3 and 1.4 that deal with iodine chemical forms in containment. Projects in this area are expected to continue at a constant level of effort. Further work will address source terms used with these Regulatory Guides

Other research at ORNL contributes to the NRC's Severe Accident Research Plan (documented in NUREG-1365, Rev. 1). These efforts include work on boiling-water reactor (BWR) core-melt progression and in-vessel strategies for addressing potential severe accident conditions. ORNL staff collaborate with Sandia National Laboratories and Idaho National Engineering Laboratory to improve the MELCOR code for LWRs and extend its applicability to scenarios for severe accidents in BWRs. Other severe accident code development work supports NRC cooperative research agreements with Germany (CORA-BWR experiments) and with seven other nations to develop and validate computer codes for modeling fission product behavior and core-melt progression under severe accident conditions (Cooperative Severe Accident Research Partners). Support is provided for other NRC-developed codes such as SCDAP/RELAP and CONTAIN.

The NRC continues to place high priority on research to ensure the integrity of reactor pressure vessels in commercial nuclear power plants. ORNL is the lead laboratory for this work, which includes the Heavy-Section Steel Technology (HSST) program, the Heavy-Section Steel Irradiation (HSSI) program, and the Surveillance Data Base, Analysis, and Standardization (SAS) program. The NRC integrates the results of these programs into its reactor regulation process and into its agreements with foreign states (e.g., the activities of the Joint Coordinating Committee for the Civilian Nuclear Reactor Safety with Russia and other states of the former Soviet Union).

The HSST program investigates issues concerned with validating safety margins for prevention of reactor vessel fracture under all feasible loading conditions. Large-scale fracture experiments and advanced analysis methods are used to investigate the impact of shallow flaws and localized thermally induced constraints in association with emergency

core-cooling scenarios. Results of experiments are factored into national consensus standards and NRC procedures. Pressure vessel investigations include supplemental pressure vessel safety research for advanced LWR designs and for the advanced reactors that the NRC is working to certify.

The HSSI program is extending databases and the basic understanding of physical mechanisms associated with radiation-induced damage (e.g., embrittlement) in pressure vessel steels. Bare metal, welds, and cladding are included. Radiation experiments are performed to verify the applicability of damage models to prototypically thick sections of each material. The program includes studies of the degree to which degraded steel properties recover when thick sections of irradiated steel are annealed at relatively high temperatures for long periods of time. R&D activities relating to irradiation embrittlement of reactor pressure vessel steels continue to be considered of the highest priority to nuclear safety by the NRC and the international community.

The SAS program maintains the national operational surveillance database on embrittlement for commercial reactors. These data are used to develop improved correlations for predicting the state of embrittlement for vessels in operating reactors. These results have direct applications in license renewal and life-extension assessments, which will continue to be major NRC concerns. Attention is given to determining the compatibility of data from other nations with the U.S. database and to possible combination of these data. ORNL leads the NRC effort to develop and examine an international database on embrittlement; this effort is coordinated with the International Atomic Energy Agency.

A Generic Environmental Impact Statement appropriate for license renewal rulemaking was developed with ORNL assistance and listed in the Federal Register for public comment. ORNL is working with the NRC to assess the comments and assist in the resolution process.

The NRC sponsors safety research to support certification of advanced LWRs. ORNL provides support in the areas of thermal hydraulics code validation, assessment of severe accident evaluation, instrumentation and control methodologies, and pressure vessel and materials studies. As the NRC has extended its considerations of advanced reactor designs, ORNL's support efforts have increased. Further extensions are anticipated in the assessment of digital systems. In addition to understanding the reliability of these systems, assessments of their impacts on overall reactor safety are needed.

ORNL carries out projects for RES in the areas of human factors research and evaluation, engineering systems assessments, and review of radioactive transport specification packages.

The journal *Nuclear Safety*, coordinated by ORNL staff, provides safety information to the nuclear industry. Publication of *Nuclear Safety* was jointly funded by the NRC and DOE in the past; however, following DOE's decision to cease funding, the NRC has taken steps to provide full funding.

Analysis and Evaluation of Operational Data

Within the NRC, AEOD serves as a focal point for the continuing independent assessment of operational performance of nuclear power plants. ORNL projects sponsored by AEOD emphasize the collection, review, analysis, and evaluation of plant safety performance data. The highly visible Accident Sequence Precursor Project identifies nuclear power plant events that are considered precursors to potential severe core-damage accidents and uses risk

assessment methodologies to determine the quantitative significance of events. ORNL is assisting in the resolution of operational performance issues, benchmarking the operating records of individual power plants for diagnostic assessments, trending events, providing technical assistance, and responding to inquiries from NRC staff on operational and safety-related issues.

ORNL operates and maintains the Sequence Coding and Search System (SCSS), the NRC's official database on reportable operational events at commercial power plants. Used to construct event sequences, SCSS is a highly structured system that supports detailed searches of operational occurrences. SCSS supports ASP analyses, NRC's performance indicator programs, and identification of common-cause failures. ORNL also maintains data systems on reactor events in other nations, international incident reports, and power plant performance indicator data and appropriate statistical models developed for the interpretation of these data. ORNL provides extensive support to AEOD through the NRC's performance indicator program by evaluating events to determine their cause, monitoring changes in plant performance, and indicating corrective actions needed to prevent plants from developing serious problems. ORNL also provides support in the development and maintenance of emergency response tools.

Nuclear Reactor Regulation

Using expertise developed in RES programs, ORNL provides technical consultation and assistance to NRR. Technical assistance is currently provided in the interpretation of nonintrusive plant component evaluation data, in analyses of fuel stability, in the review of licensing documentation, in evaluations of BWR stability phenomena, and in failure modes and effects analysis. A significant effort also involves investigations of the thermal-hydraulic stability phenomena of BWR cores or fuel assemblies.

Economic analyses and reviews of safety-related systems are conducted to support NRR's advanced reactor design certification efforts. Further increases in NRR work are expected during the next few years to assist NRC's advanced reactor design review and nuclear plant license extension activities.

Nuclear Material Safety and Safeguards

NMSS sponsors several projects at ORNL, including computer programming and documentation of criticality safety, shielding and thermal analyses of nuclear fuel facilities and package designs, licensing of enrichment facilities, technical assistance in the review and preparation of National Environmental Policy Act documents for nonreactor nuclear facilities, safety and environmental review of licensee facilities, assessment and development of Russian safeguards and security requirements, and review of terminated license files for radioactive materials handling facilities. ORNL also provides technical support in reviewing the design, construction, operation, and performance of low-level waste facilities. These efforts are expected to continue.

Technical assistance is provided for assessing the effectiveness of the low-enriched uranium (LEU) Reform Rule and its implementation in maintaining the NRC's desired level of safeguards for users of nonstrategic special nuclear materials. Terminated license files are reviewed to determine whether the sites and licensees were demonstrated to meet present criteria for release of the site, based on public health and safety considerations, and whether

the information provided by the licensee was sufficient to determine releasibility. Funding for NMSS work is expected to remain relatively stable or to increase over the planning period.

Other Offices

ORNL provides technical assistance in the conduct of inventory verification, analysis of special nuclear materials samples, preparation of site-specific material standards, and review of environmental assessments and operating procedural changes. ORNL staff members also provide consultation and technical assistance to the NRC Advisory Committee on Reactor Safeguards and support to the Office of State Programs.

5.2.1.2 • U.S. Department of Defense

ORNL carries out R&D for the major Department of Defense (DOD) services—the Army, Navy, Marines, and Air Force—and for joint agencies such as the Defense Nuclear Agency, the Advanced Research Projects Agency (ARPA), and the U.S. Transportation Command (USTRANSCOM). Several projects are managed by Energy Systems organizations, and all projects are considered part of an Energy Systems central organization.

Army

ORNL research for the Army includes programs in materials science and technology, optics, instrumentation and control systems, robotics and intelligent systems, human-machine interface technology, transportation systems, operations research, and environmental and work force analysis.

Primary responsibility for managing technology base research within the Army is assigned to the Army Research Laboratory (ARL). ORNL is developing several cooperative programs in fundamental research with ARL, including work in advanced materials, microelectronics, robotics, and advanced computing.

Work will continue on a major research initiative concerning the aging of materials, electronics, and other components in Army weapon systems. A major materials study will continue for the Armament, Chemical and Munitions Command, and related work will continue in advanced composites, ceramics, carbon/carbon bonding, intermetallics, and related technologies. Research in material processing and analysis techniques, including mathematical and computational modeling of crack propagation, will continue. These projects are designed to develop advanced armor and shielding as well as lighter-weight components for increased mobility of weapon systems and vehicles. Advanced shielding materials and processing concepts will be evaluated for ARPA, the Army Corps of Engineers, the Ballistics Research Laboratory, the Tank Automotive Command (TACOM), and other agencies. Work also continues on advanced materials for reentry vehicles and space applications.

Initiatives continue in advanced instrumentation and robotics and intelligent systems technology, including advanced robotics concepts for ARL, Fort Belvoir R&D Center, and related agencies. Programs to defend against high-energy agile laser technology for the battlefield are also planned. These include teaming with TACOM to develop viewfinders for tanks and armored vehicles to reduce the potential for laser damage to the eyes of soldiers on the battlefield. Stand-off detection of agents using advanced laser techniques will be studied. Communication and information technology for battlefield integration will be evaluated.

Researchers in the ORNL Robotics and Process Systems Division continue the development of automated systems for battlefield rearm technology. Current projects include the Advanced Integrated Robotics Rearm System, the Modular Artillery Ammunition Delivery System, and the Smart Crane Ammunition Transfer System.

ORNL continues to support major environmental assessments, including assisting the Army's program manager for chemical demilitarization to prepare site-specific environmental impact statements for the disposal of chemical agents and munitions. ORNL also assists the Army in the development of emergency response plans for installations that store chemical agents and munitions. For the DOD Installation Restoration Program (IRP), ORNL is assisting the Army's Environmental Agency in analyzing scientific and regulatory issues and in defining cleanup criteria for hazardous waste sites. A number of Army waste sites throughout the country must be remediated according to Environmental Protection Agency (EPA) policies and guidelines. ORNL scientists are using their knowledge of the EPA's regulations and risk assessment strategies to define the necessary cleanup criteria for the Army. New environmental assessment and control technology will be developed and demonstrated; this includes topography, bioremediation, and chemical process technology for the Army Environmental Agency. Other plans include instrumentation to support the test and evaluation community for Test and Evaluation Command and evaluation of advanced artillery system concepts and designs for the Combat Artillery School.

ORNL will expand its environmental analyses of the potential impacts of changing military operations or broader programmatic missions at specific sites. This work includes developing new environmental measurement and analytic techniques for laboratory and field applications. Work is also expanding in analytical chemistry and environmental technology to characterize chemicals (such as military fuels) and their by-products and to develop biological indicators for environmental and health assessments. A major new initiative has begun to plan, demonstrate, and evaluate pollution prevention technologies. The initiative includes evaluation of environmentally safe materials as well as hazardous waste minimization technologies.

R&D for the Army in operations research and transportation systems, energy conservation, energy security, fuels research, and advanced engineering command continues. Included among these projects are the development of telecommunications systems prototypes and a model for the coordination of routing and scheduling military convoys over the U.S. highway system. Research to develop regional economic assessment decision support systems for recruiting and for force structure analysis for the National Guard Bureau and the Army Reserve and Recruiting Command is expected to grow moderately over the planning period. ORNL is providing analytical techniques for force structure and mobilization planning and related civilian missions.

The Army's Chemical Research, Development, and Engineering Center is supporting efforts to refine techniques for the detection of biological and chemical materials in the air. Various combinations of lasers, optical fibers, and advanced spectroscopic techniques are being used to support the Army's efforts to develop instruments that can be used on future battlefields. Efforts continue to provide a computational framework for inferring radiation dose from bioassay measurements.

A series of Applicable or Relevant and Appropriate Requirement investigations has been conducted at contaminated Army sites. Efforts continue to provide a computational framework for inferring radiation doses from bioassay measurements. Technical assistance is

provided to the Army's Environmental Hygienic Agency in preparing Material Safety Data Sheets for incorporation into DOD's Hazardous Material Information System.

Work also continues for the Picatinny Arsenal to develop, evaluate, and test new designs for compulsators and power systems for electromagnetic and advanced gun systems.

Navy and Marine Corps

ORNL conducts research for the Navy and Marine Corps in engineering systems, instrumentation, data systems, reliability and maintenance, materials R&D, fuel supply and use, diesel testing, human factors engineering, energy conservation, and waste disposal. This research has diverse applications and has contributed significantly to many Navy and Marine Corps programs located at a variety of laboratories and institutions.

ORNL's Navy Mobility Fuels Forecasting System is being used to evaluate the fuel production effects of the U.S. Clean Air Act. ORNL plays an important role in instrumentation and engineering R&D for the Carderock Division, Naval Surface Warfare Center (CDNSWC), the Navy's primary research, development, test, and evaluation center for naval vehicles. Two primary areas of interest to the CDNSWC are ship and submarine silencing and methods to design and test high-strength hulls and components. ORNL assists the CDNSWC in the design and development of R&D instrumentation systems for experimental models of proposed submarine designs, the development of new ship and submarine designs, and support for the current fleet. ORNL also continues to evaluate new technologies for the Navy's advanced submarine R&D program, which is planned to support the new emphasis on ARPA and the Navy.

ORNL provides a variety of design, engineering, and development support for the Coastal Systems Station in the areas of submarine countermeasures, amphibious warfare, naval special warfare, and mines and mine countermeasures. ORNL is also providing electronics development and human factors engineering support for the Naval Medical Research Institute in areas related to divers and diving. ORNL research for the Naval Air Systems Command involves the design and evaluation of advanced part-task trainers for Navy missile systems. Issues related to the ability to ensure high levels of training effectiveness and the relationship between trainer fidelity and human performance are key concerns involved with appropriate mental models and subsequently with effective trainer interface design.

For other Navy facilities, R&D continues on instrumentation and equipment reliability and maintenance; methods are being explored to determine optimal times for preventive maintenance. ORNL research also involves productive base analysis that addresses the capability of U.S. industry to produce defense material in a time of war. Research continues on new techniques to modernize naval systems, especially in the areas of logistics, mobilization planning and modeling, command and control, marine telecommunications, environmental technology, computer-aided instruction, and robotics and intelligent systems. Other R&D efforts include electronic component design cost-effectiveness, life-cycle analysis, and prototype development for the Naval Sea Logistics Center, a computer-aided research project for the Naval Sea Systems Command.

For the Office of Naval Research, in conjunction with the DOE Environmental Measurements Laboratory, Argonne National Laboratory, and Los Alamos National Laboratory, ORNL is tracking the movement of radionuclides to characterize the extent of radioactive contamination in the Arctic basin resulting from nuclear testing and waste disposal conducted by the former Soviet Union.

ORNL also provides technical assistance to the Navy Environmental Health Center in Norfolk, Virginia, by preparing Material Safety Data Sheets and hazardous material assessment reports to support the hazard communication standards of the Occupational Safety and Health Administration, the Superfund Amendment Reauthorization Act, and the right to know of the community.

ORNL has conducted several materials R&D programs for the Navy. Among them is a program to fabricate pressure hull prototypes made of polymer matrix composite for submersible vehicles.

ORNL staff provide technical assistance to the Navy's Radon Assessment and Mitigation Program. The screening phase has been completed; extensive assistance is being provided for data quality assurance and data management. Consultation with facility engineers facilitated efforts to reduce radon exposures at sites where very high concentrations were discovered. In the assessment phase now under way, additional sampling is being conducted at selected bases to identify all buildings with unacceptable levels of indoor radon.

Air Force

For the Air Force, ORNL performs research on environmental systems, advanced materials, advanced fuels, data systems, waste management, and related areas. A major economic analysis activity supports the Air Force Civil Engineering Support Agency (AFCESA) and the Air Force's major commands. ORNL performs economic analysis and provides technical support for evaluating the use of private-sector financing to augment government funding to achieve a more rapid delivery of new facilities and services. Other support to the AFCESA includes evaluation of Air Force base energy requirements to assess whether these requirements can be met cost-effectively by increased coal consumption.

In support of IRP, ORNL is assisting the Air Force's toxicology program at Wright-Patterson Air Force Base. The five-volume IRP toxicology guide prepared by this program, covering 70 organic compounds, incorporates a wide range of toxicological data, including carcinogenicity, genotoxicity, teratogenicity, and short-term and long-term exposure effects on humans. New information dissemination technology (e.g., CD-ROM and laser disk readers) will be evaluated and implemented.

For the Wright Laboratory, ORNL is performing research in multisensor integration algorithms for hypercube computer architectures. Hypercube computer architectures offer supercomputer capabilities in a small volume (which is ideally suited for robots and satellites). This research augments and complements DOE robotics multisensor integration research being carried out at ORNL. ORNL is also providing R&D support to the Wright-Patterson Air Force Base in weigh-in-motion systems.

A major environmental R&D activity will continue to support the Air Force Environmental Impact Analysis Process in which both programmatic and site-specific analyses of Air Force actions are addressed. ORNL conducts environmental compliance assessments for various Air Force commands.

Military Transportation

ORNL has conducted extensive R&D for the DOD transportation agencies. ORNL's Center for Transportation Analysis blends complementary work for DOE, the Department of Transportation, and the various defense transportation agencies, linking such WFO sponsors as the Federal Aviation Administration, the Federal Highway Administration, and the three

components of USTRANSCOM—the Air Mobility Command (AMC), the Military Sealift Command, and the Military Traffic Management Command. The AMC Deployment Analysis System has been expanded to take on the task of planning and scheduling the operation of the air refueling fleet.

Support for the DOD transportation user community will be provided through the Oak Ridge Transportation Technology Center (ORTRAN), described in Sect. 5.1.2.1. Areas of research include decision support systems and modeling; development of a program for efficient, standardized noncombat vehicles; and planning and development of transportation technologies that support efficient deployment.

Defense Nuclear Agency

ORNL performs research for the Defense Nuclear Agency in support of the Human Response Program. The human factor in the military nuclear environment is addressed through models and databases that predict the human response in all nuclear threat situations. Research is carried out through expert integration of state-of-the-art radiation transport and human response data. ORNL is satisfying the conditions for this program as defined under the DOD Qualified Research Requirements documents through a multiphase plan that includes definition and analytic validation of the initial and protracted radiation environments, shielding calculations for tactical armored vehicles, and extensive comparison of existing and new methods to assess radiation impacts on military vehicles and human beings.

The Defense Nuclear Agency also supports research at ORNL to define more accurately the effects of nuclear radiation on the crew and components of tactical combat vehicles. In addition, it supports the Radiation Shielding Information Center to provide an information analysis center for Defense Nuclear Agency contractors involved in radiation transport R&D.

Other Department of Defense Agencies

ORNL performs site characterizations and performance assessments for potentially contaminated sites and for new facilities at DOD installations (Air Force, Air National Guard, Navy, Army) with the primary objective of assessing contamination problems. ORNL works to apply innovative techniques, to identify and pursue research needs based on observations at numerous field sites, and to communicate lessons learned and research applications in the technical literature. ORNL is also aggressively pursuing new projects through the Advanced Research Projects Agency's Technology Reinvestment Program.

5.2.1.3 • National Aeronautics and Space Administration

The NASA Earth Observing System Data and Information System (EOSDIS) is a key component of the U.S. Global Change Research Program. ORNL is one of eight Distributed Active Archive Centers (DAACs) through which the scientific research community can acquire data and information from EOSDIS. The ORNL DAAC is described in detail in Sect. 5.1.6.2.

5.2.1.4 • U.S. Department of Health and Human Services

The U.S. Department of Health and Human Services supports research in carcinogenesis, protein engineering, protein crystallography, genetics, and toxicology. Funding from this source is expected to remain reasonably constant over the planning period. The majority of funding is from the National Institutes of Health (NIH); some funding is from the U.S. Food and Drug Administration.

The National Cancer Institute (NCI) supports research on the expression of preneoplastic markers in tracheal cells. ORNL is studying cell interaction and the role of transforming growth factor β (TGF-β) in the control of tracheal cell proliferation. Studies involve the changes in response to growth factors as cells progress from preneoplasia to malignancy. During the next five years, questions about the responses of ecological systems and how they relate to potential human health effects will be addressed.

The National Institute for Child Health and Human Development supports a program on the induction of insertional mutations by means of transgenic technology. Caused by integration of foreign DNA into the host genome, such mutations are valuable for correlating gene structure with function.

The National Institute of General Medical Science supports studies to improve our understanding of hydrogen-bonded biological systems. ORNL scientists are investigating the hydrogen-bond structure of macromolecules with X-ray and neutron diffraction and with analysis programs running on supercomputers.

The National Institute for Environmental Health Sciences (NIEHS) supports several large projects on the genetic effects of chemicals. The mechanisms by which gene mutations and chromosome aberrations are induced in germ cells are investigated. Both induced and spontaneous mutations are analyzed at the DNA level. Also studied are organismic effects in first-generation offspring of mice exposed to chemicals.

NIEHS also supports investigations into the mechanisms of early mammalian development. In this project, gene action during preimplantation stages and very early developmental pathways are investigated with the aid of chemicals that disrupt normal processes. The Environmental Mutagen Information Center (see Sect. 5.1.6.2) also receives support from NIEHS.

NIH supports an in-depth investigation on the mechanisms involved in a lethal autoimmune disease caused by the scurfy (*sf*) mutation. Also supported by NIH are studies on mice afflicted with polycystic kidneys. This condition, resulting from an insertional mutation, provides a close model for a similar human disease. For the National Heart, Lung and Blood Institute and NCI, the ORNL Nuclear Medicine Program is developing a basic understanding of the chemistry and physiology of cerebrovascular and cardiovascular imaging agents. Osmium/iridium generators have been provided to collaborating researchers who evaluated various applications for cardiovascular imaging.

Analytical tools developed for use by the Agency for Toxic Substances and Disease Registry (ATSDR) for evaluating reports of clusters of health effects near hazardous waste sites will be made available via a user-friendly program for a microcomputer. ORNL also provides guidance to ATSDR on the performance of health assessments at hazardous waste sites on the Superfund List. Methodologies are being developed to predict acute and chronic health effects resulting from exposure to hazardous chemicals. ORNL has also developed a geographical information system for use in evaluating health effects.

The National Institute on Aging supports frozen embryo banks for several mouse and rat strains developed for aging studies. The National Institute of Allergy and Infectious

Diseases supports investigations of thymus dysfunctions in a mutant mouse that may be a model for certain autoimmune diseases. ORNL is also supporting studies of the molecular basis for polycystic kidney disease for the National Institute of Diabetes and Digestive and Kidney Diseases.

5.2.1.5 • U.S. Environmental Protection Agency

ORNL's work for the Environmental Protection Agency (EPA) addresses numerous health and environmental problems and issues. Research focuses on identifying the effects of pollutants associated with energy production processes, effluents, and disposal.

ORNL staff members are conducting ecosystem simulations to relate the effects of contaminant releases to ecological responses. Other research addresses the toxicity of leachates from solid waste and the human health effects from incineration of hazardous chemicals. ORNL also provides technical support to the National Acid Precipitation Assessment Program II and measures the response of high-elevation forest ecosystems to atmospheric deposition.

For the new Environmental Monitoring and Assessment Program (EMAP), ORNL staff members are developing an analysis of ecological indicators and integrated assessment approaches for the overall EMAP.

Literature reviews and chemical hazard information profiles are prepared for EPA-selected topics and chemicals. ORNL will continue to provide administrative management, coordination, and information support to the EPA GENETOX Program. Support for the Chemical Unit Record Estimate (CURE) database, including the development of a personal computer–based version of selected information from the CURE master file on over 1900 chemicals, will also continue (see Sect. 5.1.6.2).

Health risk assessment activities are addressing chemical carcinogeneticity and chronic toxicity, electromagnetic fields, and diesel emissions. The EPA is also supporting research at ORNL to evaluate the use of physiologically based pharmacokinetic models in the risk assessment process.

The ORNL Center for Risk Management (see Sect. 5.1.6.4) is evaluating the feasibility of developing nationally consistent soil quality criteria for use in determining required cleanup levels at contaminated sites. The project involves review of approaches to soil quality criteria, database development, and analysis of the degree of groundwater protection provided by proposed criteria.

5.2.1.6 • National Science Foundation

The National Science Foundation (NSF) supports studies of spatial gradients in nutrient cycling and their effect on stream ecosystem stability, drawing on the Walker Branch Watershed and using radioisotope tracers to research key factors in stream response. The understanding derived from this research will benefit ORNL studies of disturbed ecosystems on the Oak Ridge reservation that are being conducted in concert with remedial action efforts.

ORNL continues to provide technical assistance to the Division of Polar Programs in its effort to evaluate the environmental impacts of the U.S. Antarctic Program. ORNL is developing site- and project-specific environmental impact assessments. Emphasis is being placed on waste and fuel management, logistic support facilities, sensitive resources, and global concerns for the Antarctic environment.

The NSF supports research to evaluate the scientific bases for assumptions used in risk assessment. The results are intended for use by federal agencies responsible for regulating human exposure to chemical carcinogens. The NSF also provides support for cryogenic preservation research. An award-winning technique for freezing *Drosophila* embryos, developed at ORNL, was funded in part by the NSF.

The NSF's Industry/University Cooperative Research Program funds the University of Tennessee at Knoxville's Measurement and Control Engineering Center, a collaboration with ORNL and industrial partners Eastman Chemical, Dow Chemical, DuPont, and Perkin-Elmer. The Measurement and Control Engineering Center has capabilities related to analytical instrumentation, process controls, signal/image processing, and predictive maintenance.

5.2.1.7 • Federal Emergency Management Agency

ORNL programs for the Federal Emergency Management Agency (FEMA) include a range of research, development, and technical assistance activities in support of national preparedness for major emergencies. At FEMA's request, ORNL serves as an independent center of expertise in areas ranging from engineering assistance to analysis and assessment.

Engineering work includes assisting in hardening civil defense installations against electromagnetic pulse effects, developing devices that protect against the effects of electromagnetic pulses, and testing equipment. Analysis and assessment activities include building economic models of preparedness options, assisting with the use of computer graphics, studying human behavior in emergencies, and working on state-of-the-art assessments on various programs and issues. These activities also include

- development of a national system for infrastructure information,
- emergency preparedness for hazardous material accidents, including those involving chemical weapons,
- impacts of disasters,
- postdisaster economic recovery,
- data sources for emergency management,
- shelter concepts for emergency protection,
- civil defense program planning,
- risk communication and public awareness,
- evacuation planning for natural and man-made disasters,
- public alert/notification system performance,
- preparedness for special populations and institutions, and
- adequacy of training for emergency workers.

5.2.1.8 • U.S. Agency for International Development

ORNL serves as a center of expertise for the U.S. Agency for International Development (AID) Office of Energy and Infrastructure in the Bureau of Research and Development on energy planning and policy development and renewable energy applications. ORNL's activities include research; analysis; technical assistance; project development, implementation, and evaluation; and information dissemination. Efforts in energy planning and policy development emphasize energy efficiency improvement, environmental management, transportation systems, R&D roles, institution building, and technology cooperation. In renewable energy applications, ORNL emphasizes biomass energy systems and rural/decentralized applications. ORNL also supports programmatic activities in other AID components.

5.2.1.9 • U.S. Department of Transportation

The Department of Transportation provides funding to ORTRAN (see Sect. 5.1.2.1) and also supports the Center for Transportation Analysis, which covers all transportation modes. ORNL is assisting the Federal Highway Administration, the National Highway Traffic Safety Administration, the Office of Pipeline Safety, the Federal Transit Administration, the Federal Aviation Administration, and the Bureau of Transportation Statistics in research areas that include development of freight and passenger demand models; assessment of data quality and data consistency of highway statistics; development of data collection methods and advanced data management systems to improve data integrity and availability; analysis of nationwide surveys to address issues in current or future national transportation policies; development of methods to statistically link data sources to study intermodal traffic; and research on intelligent vehicle and highway systems.

5.2.1.10 • U.S. Department of Commerce

ORNL is providing technical leadership in support of the Coastal Change Analysis Project (C-CAP). C-CAP is sponsored by the Coastal Ocean Program of the National Oceanic and Atmospheric Administration (NOAA) and administered through NOAA's National Marine Fisheries Service. ORNL's primary responsibility is to conduct R&D on land-cover monitoring in the coastal regions of the United States, in support of a national effort to monitor land cover gains and losses.

ORNL provides planning, technical coordination, and implementation of regional projects designed to employ the C-CAP protocols. Each project involves collaboration with a university, state government agency, or other regional organization. Technology transfer will be a key technical requirement in the collaborative efforts. Regional projects include Galveston Bay, the Louisiana coast, Tampa Bay, the South Carolina coast, the North Carolina coast, the Rhode Island coast, the St. Croix estuary, San Francisco Bay, the Columbia River estuary, the Alaska coast, and south Florida. ORNL processes satellite images and other data in support of these regional projects, develops improved methods and techniques for measuring spectral change, develops new methods and techniques for assessing accuracy in large spatial databases involving change over time, and is assisting in establishing an operational center for C-CAP.

5.2.1.11 • Other Federal Agencies

ORNL provides technical support to a variety of other federal agencies, including the U.S. Department of Agriculture (USDA), the U.S. Department of State, and other agencies.

The Laboratory anticipates collaborative work with the USDA, including the Agricultural Research Service, the U.S. Forest Service, and USDA research laboratories.

Support provided by the State Department for work performed for the International Atomic Energy Agency and the United Nations Educational, Scientific, and Cultural Organization is expected to continue. ORNL is also assisting the U.S. country studies program in support of the Intergovernmental Panel on Climate Change, which is led by the State Department and supported by DOE, EPA, and AID. ORNL continues to assist the National Park Service in evaluating the environmental impact of proposed extensions of the Foothills Parkway, adjacent to the Great Smoky Mountains National Park.

ORNL is assisting the Tennessee Valley Authority (TVA) in an assessment of the potential for biomass energy within the TVA power system. In addition, a major contract is in progress to conduct R&D for TVA in areas of mutual interest, including the development of advanced diagnostics, advanced instrumentation and controls for TVA power plants, and techniques to improve the efficiency and reliability of TVA's transmission and distribution systems; assistance in improving end uses; and evaluation of the health effects of electromagnetic fields.

Support is provided to the Bureau of Labor Statistics in artificial intelligence systems to provide estimates of consumer prices index and survey automation. Work is anticipated in support of the Office of National Drug Control Policy and its various support agencies.

ORNL provides support in environmental management of water resources to several other federal agencies. For example, ORNL staff serve as technical advisors to the Bureau of Indian Affairs and the U.S. Army Corps of Engineers on environmental issues such as hydropower impacts on fish and wildlife and instream flow policies.

5.2.2 • Nonfederal Organizations

ORNL performs research for and in collaboration with many nonfederal entities, both public and private. These efforts support DOE's mission to apply the resources of the national laboratories to issues and problems of national importance, especially in the areas of energy resources, environmental quality, and economic competitiveness.

5.2.2.1 • Electric Power Research Institute

The Electric Power Research Institute (EPRI) funds research at ORNL in areas related to the generation and efficient use of environmentally acceptable electric energy. The Laboratory expects to continue research in these areas for EPRI during the planning cycle.

EPRI continues to fund research at ORNL in areas related to the efficient use of electric energy. An efficiency research project now under way is testing full-size ice storage systems for cooling commercial buildings. Also under way are projects to develop diagnostic procedures for detecting toxic by-products of power circuit breaker gases and to develop chlorofluorocarbon (CFC) replacement fluids in commercial chiller units. EPRI cooperation and support are expected for major DOE programs at ORNL in areas of health effects of electric and magnetic fields, high-voltage direct current transmission, and real-time control of transmission and distribution systems.

ORNL's expertise in biomass energy is being applied to analyzing the potential of biomass feedstock for electric power plants. Interaction with the ORNL Biofuels Feedstock Development Program is expected to increase.

EPRI is cofunding the development and demonstration at ORNL of intelligent control systems for nuclear power plants (see Sect. 5.1.2.3). This includes such topics as validation and verification guidelines for software used in digital nuclear plant control systems and development of portable software that runs on a variety of hardware platforms.

ORNL carries out technology development for EPRI in the area of high-temperature structural design methods and fracture assessment procedures for advanced reactors and other high-temperature power plant components. In these activities, ORNL serves as EPRI's R&D arm in collaborative studies between EPRI, the Central Research Institute for Electric Power

Industry in Japan, and the Central Electricity Generating Board in the United Kingdom. Results of these joint studies help to meet identified needs in DOE's reactor programs.

Assessment of the role of volatile salts such as ammonium chloride in the carryover of corrosive species in steam generator circuits is limited by the lack of data and predictive models. Experimental data are being obtained at ORNL and incorporated into broader thermodynamic models.

EPRI also funds research at ORNL in the application of chaos theory to diagnosis and control of power generation systems. Recent activities have focused on characterization of fluidized bed combustion hydrodynamics and the development of data analysis algorithms for extracting nonlinear information from fluidized bed measurements. As part of this activity, ORNL has developed a close collaboration with the Technical University of Delft in the Netherlands and with Babcock and Wilcox (B&W), a major U.S. boiler manufacturer. It is anticipated that EPRI-sponsored fluidized bed research will continue, augmented by a major new thrust in the application of chaos to analyzing and controlling boiler flame dynamics, especially in regard to emission reduction.

Associated with EPRI research is work funded by the B&W Owners Group to develop an improved control system for currently operating B&W reactors. The project objectives are identification, documentation, and resolution of problem areas in the current control system; development of the optimum system configuration; exploration of technological improvements in control design methods; and provision of features that meet the expanded scope of control for the new control system. ORNL's project is a control algorithm that will be implemented by the B&W Owners Group on new digital control hardware.

5.2.2.2 • American Petroleum Institute

The American Petroleum Institute supports research at ORNL to evaluate the pharmacokinetics and pharmacodynamics of benzene in humans. The work is intended to provide a better estimate of the risk of developing leukemia following exposure to low doses of benzene.

ORNL also provides support to the American Petroleum Institute in the area of global climate change by developing inventories of greenhouse gas emissions associated with petroleum product combustion. The inventories will focus on energy consumption and fugitive gas losses through production, refining, and distribution.

5.2.2.3 • Joint Institute for Energy and Environment

The Joint Institute for Energy and Environment is an organizational entity established by ORNL, the Tennessee Valley Authority, and the University of Tennessee to conduct research and other collaborative activities on critical topics related to energy and the environment. Skills and facilities from theoretical research through laboratory explorations to full-scale demonstration projects are combined with policy and social science expertise to address research topics such as the science and policy implications of climate change; the role of environmental education, training and technology transfer in global economic development; domestic and international energy and environmental policy; and energy production and conservation.

5.2.2.4 • Other Nonfederal Organizations

Private industry has joined with ORNL through CRADAs, licensing agreements, user agreements, and other mechanisms. ORNL also interacts with many other nonfederal entities, including

- Battelle Laboratories,
- SEMATECH,
- EG&G Energy Measurements, Inc.,
- the General Electric Company,
- the Florida Institute of Phosphate Research,
- the Metropolitan Edison/General Public Utility,
- the Pacific Power and Light Company,
- the Soap and Detergent Association,
- the states of California, Virginia, and Alaska,
- the Canadian Atomic Energy Commission,
- the Federal Republic of Germany Umweltbunesamt,
- the Japan Atomic Energy Research Institute,
- the Korea Advanced Energy Research Institute,
- the National Institute of Radiation Protection of Sweden,
- the United Kingdom Atomic Energy Agency,
- the International Atomic Energy Agency,
- the National Geographic Society,
- the Center for Indoor Air Research,
- the Gas Research Institute, and
- Oak Ridge Associated Universities.

5.3 • Laboratory Directed R&D Program

The principal objective of the ORNL Laboratory Directed Research and Development (LDRD) Program is to provide financial support for innovative R&D ideas that, while within the general mission of the Laboratory, have no direct programmatic funding. Such ideas can and do lead to productive new technical directions for the Laboratory, DOE, and the nation. The program, which obtains its funds from DOE through an overhead charge to all other Laboratory programs, operates under the authority of DOE Order 5000.4A, "Laboratory Directed Research and Development" (April 9, 1992). All LDRD project funding requires the approval and authorization of the Laboratory director.

The LDRD Program comprises two major activities: the Seed Money Fund and the Director's R&D Fund. The Seed Money Fund is a continuation of the original ORNL Seed Money Program initiated in 1974; the Director's R&D Fund was added in 1983. The approved FY 1994 budget was $10.2 million; $2.5 million was allocated for the Seed Money Fund, and $7.5 million was allocated for the Director's R&D Fund. The remaining $200,000 was placed in an LDRD capital equipment fund. All of the capital equipment funds were spent on FY 1994 Director's R&D Fund projects. The total budget authorized for LDRD amounts to less than 2% of the total operating budget for ORNL. Table 5.17 lists funding for FY 1993–FY 1996.

Table 5.17
Laboratory Directed R&D funding by fiscal year
($ in millions—BA)

	1993	1994	1995	1996[a]
Total funding	10.2	10.2	12.7	12.7

[a]Estimated.

Proposals for Seed Money Fund projects are accepted directly from the Laboratory's scientific and technical staff at any time of the year, are peer reviewed, and are selected for funding with the assistance of a Proposal Review Committee composed of representative scientific and technical staff. (Requests for less than $15,000 can be approved by the LDRD Program Manager.) Each of these nominally one-year projects is generally funded at less than $120,000; the average project budget in FY 1993 was $66,889.

Director's R&D Fund proposals are solicited from the scientific and technical staff in June and are reviewed through line management; most are selected by the Laboratory's R&D Strategic Planning Committee, which is composed of senior Laboratory managers and research staff members. These projects may continue for a maximum of three years, although many have durations of one to two years. The average FY 1993 budget for these projects was $186,387; total budgets for three-year projects average about $500,000. From 5 to 10% of the Director's R&D Fund is allocated individually by the Laboratory associate directors.

Unlike the Seed Money Fund, the Director's R&D Fund is targeted at specific research topics that are considered important to the future of the Laboratory. These topics are selected annually by the ORNL R&D Strategic Planning Committee. For FY 1995, the committee chose two focus areas, one aimed at an emerging capability and one with a programmatic focus. The committee also elected to devote 40% of the available funding to each of these areas, with the remaining 20% reserved for exceptionally strong proposals from other areas, irrespective of topic. The two focus areas are instrumentation (emerging capability) and pollution prevention technologies (programmatic focus). Nine new projects have been funded.

Providing multiple routes of access to LDRD funds maximizes the likelihood that novel ideas with scientific and technological merit will be recognized and supported. The selection process allows for the fact that new ideas are generally initiated by R&D staff, provides for peer review of proposals, and engages management in fostering projects that are oriented to the strategic directions of the Laboratory.

The LDRD Program is administratively part of the ORNL Office of Planning and Management. The position of program manager rotates every two years among members of the scientific and technical staff of the Laboratory. Additional descriptions of ORNL's LDRD Program can be found in

- Accomplishments of the Oak Ridge National Laboratory Seed Money Program, DOE/ER-0274, U.S. DOE, 1986;
- A Review of the Oak Ridge National Laboratory Seed Money Program, DOE/ER-0319, U.S. DOE, 1987; and

- Measuring Investment in R&D Excellence: A Study of Laboratory Directed Research and Development at the Nine DOE Multiprogram Laboratories, DOE/ER-0361, U.S. DOE, December 1992.

The program operates efficiently and is held in high regard both internally and externally. For all divisions, the overall return of new work for the Laboratory is approximately four times the program's investment. The program provides the scientific and technical staff with morale-boosting incentives to be innovative. Many of the honors, awards, and new programs at the Laboratory have their origins in work supported by the LDRD Program; in 1992, ORNL received three R&D 100 awards for developments initiated through the LDRD program.

6 • Critical Success Factors

ORNL has included "Business Practices" as a mission area in its R&D Strategic Plan (see Sect. 3). This area addresses the critical success factors identified in the DOE Strategic Plan; its identification as a mission area indicates ORNL's commitment to excellence in its approach to human resources; environment, safety, and health (ES&H); management practices; and communication and trust.

6.1 • Human Resources

Human resources plans for ORNL draw on *Focus on the Future: Strategic Plan for Human Resources,* Martin Marietta Energy Systems, Inc., January 1993. Goals have been established in four areas: valuing diversity, exhibiting genuine concern for the quality of life and morale of our people, providing opportunities for enhancing skills, and promoting and celebrating success.

ORNL is working to attract and retain staff members with the skills and abilities needed to carry out planned programs. This effort includes encouraging professional growth, recognizing achievement, and providing an environment consistent with corporate values and workforce diversity that affords equal employment for all.

6.1.1 • Valuing Diversity

ORNL's diversity goal is as simple as it is ambitious: for the mix of people in our sphere of activity to mirror the larger community of the United States by the year 2003. To attain this goal, ORNL will continue its work to build and maintain an inclusive environment. In addition to a high-level emphasis on equal employment opportunity (EEO) and affirmative action (AA), the Laboratory will work toward increasing the cultural diversity of the workforce, promoting acceptance of and appreciation for cultural diversity, and accommodating the needs of a changing workforce. *Diversity Works,* a newsletter published by the Office of Workforce Diversity (formerly the EEO/AA Office), will serve as an important means of communicating information on programs and activities in these areas.

Equal Employment Opportunity and Affirmative Action Program

As a business unit of Energy Systems, ORNL is working to fulfill the vision articulated in the *Strategic Plan for Equal Employment Opportunity and Affirmative Action,* Martin Marietta Energy Systems, Inc., 1991. The ORNL EEO/AA Strategic Plan Implementation

Committee has formulated a long-range strategy for implementing the Energy Systems Strategic Plan.

The Laboratory is committed to equal employment opportunities for its employees and for applicants who seek employment at ORNL. An ongoing AA plan, administered through the Office of Workforce Diversity within the Human Resources Division, ensures that all employment and promotion decisions are predicated on the principle of equal opportunity. Statistics on employment of women and minorities in 1988 and 1993 are shown in Tables A.7 and A.8 in the Appendix.

Support for the EEO/AA program begins at the top and is communicated down to all other levels of management and supervision to foster a shared sense of responsibility for its success. Accountability for support of EEO/AA program activities is addressed in measures of performance for management staff members. A Diversity Council, comprising representatives from senior Laboratory management and employees, develops strategies for ORNL to meet its own and other Energy Systems EEO/AA challenges. The Annual EEO/AA Awards Breakfast provides recognition to individuals and divisions that have made outstanding contributions to the EEO/AA program.

Increasing the Diversity of the Workforce

ORNL actively seeks to recruit and develop minority candidates for management openings. These efforts will continue during the planning period. The professional growth programs described earlier will provide an internal source of candidates for key management positions, and external recruiting efforts will be intensified.

The ORNL Committee for Women was established in October 1993 to pursue the goal of making ORNL a preferred workplace for women—and a better overall institution—into the 21st century. The committee is charged with raising issues and recommending actions to promote opportunities for women at ORNL. Activities include outreach to high school and college students and plans for a series of information bulletins on topics such as child care, mentoring, work schedule options, and summer internships.

The Laboratory is also involved in a range of cooperative research and educational activities with minority educational institutions (see Sect. 5.1.6.4). These programs provide educational and employment opportunities for traditionally underrepresented groups and also bring a culturally diverse population to ORNL. Ongoing programs include a subcontract with Xavier University that includes student and faculty participation in environmental sciences research; a summer internship program with Fort Valley State College that provides opportunities for undergraduate students in biomonitoring, geochemistry, and environmental regulatory assessment; participation as an employer in the National Consortium for Graduate Degrees for Minorities in Engineering and Science, providing opportunities for students to obtain master's degrees in engineering through summer internships and financial assistance; and a subcontract agreement with Tennessee State University for undergraduate and graduate students and faculty to assist with research and development in instrumentation.

Efforts that reach beyond the Laboratory include the Minority-Owned Business Technology Transfer Consortium, a new effort begun in 1993 to promote research and development (R&D) collaborations with minority businesses. This initiative served as a model for the Diversity Conference held in Washington, D.C., in July 1994.

The Laboratory will continue to emphasize recruiting and hiring qualified people with disabilities. Plans for recruiting and hiring people with disabilities are developed and implemented annually from the Office of Workforce Diversity at ORNL.

Promoting Cultural Diversity

Cultural diversity is promoted at the Laboratory through a variety of programs and events to recognize minority groups and individuals. Some of these are sponsored by the Office of Workforce Diversity, while others are sponsored by divisions or other organizations at the Laboratory. Examples include special programs for the Martin Luther King, Jr., birthday observance; Native American Month; Black History Month; Women's History Month, and Asian Pacific Heritage Week. Management training courses in communicating across cultural barriers and appreciating cultural diversity also serve to promote acceptance and to strengthen ORNL's commitment to an inclusive workplace.

Accommodating the Needs of a Changing Workforce

The company's part-time employment policy and the "employee convenience time" concept provide options in scheduling to employees. Progress has been made in developing "flextime" and "flexible workplace" policies to provide additional options. The flextime program provides a work scheduling system that gives employees discretion in choosing the specific hours of work each day. The flexible workplace program will allow employees with temporary disabilities to work out of their homes for a specified time and will also provide the company with a system to recruit qualified individuals with severe disabilities who may need to work at home.

The ORNL Disability Program Oversight Committee, formed in 1991, ensures compliance with policies and procedures relating to the Americans with Disabilities Act. The committee's efforts are aimed at improving access to facilities at ORNL.

6.1.2 • Quality of Life

Achieving ORNL's goal of exhibiting genuine concern for the quality of life and morale of our people will be accomplished in several ways. Human resources goals in valuing diversity, professional growth, and recognition programs provide support to this area. In addition, specific strategies in the *ORNL R&D Strategic Plan* (summarized in Sect. 3) address this issue; examples include using education programs to improve staff scientific and technical capabilities, developing and sustaining systems for fostering employee development and productivity, improving the user friendliness of support systems, and encouraging employee empowerment.

6.1.3 • Professional Growth

The diverse nature of ORNL's businesses requires a high-quality, multidisciplinary staff. The educational backgrounds of the current professional staff are shown in Table A.9 in the Appendix. During the planning period, ORNL will place additional emphasis on employee development, movement, and mentoring. Formal and informal programs are offered to enable staff members to meet new challenges.

The Laboratory's Educational Assistance Program is an effective tool for helping employees achieve their academic and career goals and for helping to ensure the availability, optimum utilization, and continuing welfare of skilled employees. The Laboratory also provides in-house development programs designed to meet specific needs for education and training. A degree program administered by American Technical Institute, originally proposed to serve a specialized group (reactor operations shift workers) at ORNL, now serves students from all three Energy Systems sites in Oak Ridge and from DOE. The performance planning process now includes the preparation of development plans by salaried minority and women staff members in an effort to identify areas for growth and development.

ORNL will continue to provide specialized training programs to address issues of concern to employees, such as sexual harassment awareness training and smoking cessation clinics. ORNL's management training includes courses that present strategies for communicating across cultural barriers and for appreciating cultural diversity. This area of management training is crucial in preparing managers for the changing work force of the 1990s.

The formal mentoring program allows participants to become better acquainted with and more visible to organizations beyond their own divisions. The interactions created by these relationships also provide employees with an opportunity to gain additional insights that are useful in developing career objectives.

The ORNL Committee for Women addresses career development issues such as education, mentoring, and workplace attitudes. The committee will study these issues and focus on those deemed critical to its goals.

6.1.4 • Recognition Programs

ORNL strives to provide a challenging environment for research and to reward excellent performance. Several financial and nonfinancial incentive and recognition programs reward outstanding contributions and significant achievements. The Special Achievement Awards Program is a financial incentive program that recognizes employee contributions at two levels in the organization.

At the division level, individuals are rewarded for overall quality of sustained performance; at the facility or major organization level, employees are recognized based on the achievement of special goals, milestones, and/or assignments of substantial impact on organizational programs. Another program pays inventors for technology licensed or transferred to private industry.

ORNL participates in the Martin Marietta Energy Systems, Inc., annual awards night, which recognizes outstanding performance in publications, technical achievement, management support service, inventions, operational performance, and administrative/technical support. Special achievements and accomplishments of ORNL employees are also recognized through announcements in a variety of in-house publications (*Energy Systems News, Lab Notes,* the electronic "Inside Line"). The ORNL Honors and Awards Office nominates employees for awards external to the organization, publicizes awards received by ORNL staff members to the Laboratory community, and maintains records of award winners.

6.2 • Environment, Safety, and Health

6.2.1 • ES&H Goals and Objectives

ORNL is committed to conducting operations and R&D in a manner that protects the environment, the public, and Laboratory staff while allowing the conduct of world-class research in a competitive manner. In attaining this goal, ORNL takes an integrated approach to ES&H matters.

The Laboratory's ES&H goals, objectives, and strategies are documented in the *Oak Ridge National Laboratory Environment, Safety and Health Implementation Plan*, ORNL-6801 (March 1994), which is summarized in Sect. 7. Individual employees are responsible for ensuring that their work is carried out in compliance with ES&H requirements. Self-assessment against high standards of ES&H compliance is becoming an essential part of the ORNL culture. A broad program supports the line organizations in addressing ES&H issues and provides internal appraisals and audits to ensure that requirements are met. The Laboratory's ES&H goals and objectives are presented in Table 6.1.

Table 6.1
ORNL ES&H objectives

Health and safety objectives

1. Maintain and continue improvement in the protection of worker safety and health.
2. Involve all our people in preventing workplace accidents and illnesses and in protecting the public from off-site releases.
3. Improve radiological protection and performance of radiological controls.
4. Achieve and maintain compliance with health and safety laws, regulations, orders, and agreements.
5. Achieve excellence in all aspects of safety and health performance.
6. Increase the satisfaction of our customers and stakeholders and their confidence in Energy Systems in managing safety and health performance for DOE facilities. Clearly understand their requirements and desires and strive to meet them.
7. Achieve integrated and consistent systems and teamwork in the medical, personnel health, industrial hygiene, industrial safety, and radiation protection areas.
8. By 1997, update Safety Analysis Reports.
9. By 1995, substantially reduce the types and quantity of hazardous substances.
10. By 1996, become recognized as a premier innovator in developing and implementing effective protection of worker safety and health.

Environmental objectives

1. Achieve and maintain excellence through protection of the environment and full compliance with applicable environmental laws, regulations, DOE orders, and agreements.
2. Over the long term, achieve a minimum-discharge operation in which raw and used materials are reduced at the source, reused, or recycled. Ensure that any remaining discharges to the air, water, or land are minimal and are not considered harmful to people or the environment.

Table 6.1
(continued)

3.	Ensure that risks to the environment and human health posed by *past* operations are either eliminated or reduced to prescribed levels through cost-effective cleanup or containment.
4.	Enlist, empower, and support all Energy Systems personnel in the challenge of protecting the environment, conserving natural resources, preventing pollution, and complying with applicable environmental laws, regulations, DOE orders, and agreements.
5.	Increase the satisfaction of our customers and stakeholders and their confidence in Energy Systems in managing the DOE facilities. Clearly understand their requirements and desires and strive to meet them.
6.	Develop and maintain an Energy Systems–wide management system for environmental information.
7.	Continually improve the self-assessment process to identify issues, determine root causes, develop and validate corrective action plans, monitor progress, verify completion, identify trends, and document lessons learned.
8.	Help DOE ensure adequate environmental protection programs in all of its activities.
9.	Improve systems for the dissemination of requirements by identifying needs for policies and procedures to implement applicable laws, regulations, DOE orders, and agreements.
10.	Become recognized as an innovator in research and development, testing, demonstrating, and transferring new environmental science and technologies.

6.2.2 • ES&H Plans and Initiatives

Strategies have been developed for addressing each of the ORNL ES&H objectives. These strategies detail the actions necessary to achieve the objectives. In addition, numerous program, compliance, and response plans provide guidance in other ES&H activities that are necessary for the continued operation of the Laboratory but do not relate specifically to the stated ES&H goals and objectives.

Facility safety documentation will be updated to accommodate the emerging nuclear safety management rules. The implementation plan strategy for the rules includes participation in DOE's Price-Anderson Amendments Act pilot program and close coordination of issues and impacts with DOE before submittal of rule implementation plans. Funding to meet implementation plan commitments is a significant issue.

Table 6.2 provides the estimated cost of safety and health for ORNL based on the Laboratory's input to the DOE Safety and Health Five-Year Plan. These estimates were developed through analysis of the expected needs at the Laboratory. Actual funding for future years has not been determined. All activities associated with these costs have been ranked using the DOE Safety and Health Risk Priority Matrix, and the results have been submitted to DOE's Oak Ridge Operations Office for transfer to the responsible primary secretarial offices.

Table 6.2
Safety and Health Plan funding by fiscal year[a]
($ in thousands)

	1995	1996	1997	1998	1999	2000
Indirect	77,392	72,368	79,081	80,974	82,811	80,893
Operating[b]						
Defense Programs	1,084	1,058	1,002	957	1,006	928
Energy Research	20,252	20,465	24,042	24,807	26,189	25,676
Laboratory Management	41,684	55,136	38,149	34,703	35,610	35,034
Nuclear Energy	3,464	3,662	2,966	3,057	3,150	3,247
Total operating	66,484	80,321	66,159	63,524	65,955	64,885
Capital equipment						
Energy Research	6,227	1,600	950	820	800	20
Laboratory Management	8,622	11,194	8,674	8,540	8,767	8,762
Total capital equipment	14,849	12,794	9,624	9,360	9,567	8,782
GPP[c]						
Energy Research	0	250	0	0	0	0
Laboratory Management	507	2,100	1,787	1,768	2,200	0
Total GPP	507	2,350	1,787	1,768	2,200	0
Line item						
Defense Programs	0	0	9,750	20,500	9,900	0
Laboratory Management	752	1,208	27,886	29,906	5,726	245
Total line items	752	1,208	37,636	50,406	15,626	245
Total Safety & Health	159,984	169,041	194,289	206,032	176,159	154,805

[a]Does not include cost from Energy Systems central organizations distributed to ORNL.
[b]Includes division administration as a direct operating expense.
[c]General plant project.

Table 6.3 provides an estimate of funding requirements for corrective actions associated with the ORNL Tiger Team Assessment. Because many corrective actions are performed as part of an individual's ordinary duties, it is difficult to completely capture all costs. This is especially true for actions funded indirectly through overhead rather than as specific requests to DOE. A significant amount of funding is still required to complete the actions in response to the Tiger Team.

The ORNL Waste Reduction Program (WRP) provides coordination and technical guidance to divisions in the reduction of waste, as well as the planning and reporting that is required by state and federal laws and DOE orders. Additionally, waste streams that are common to several divisions are evaluated by the WRP. The WRP addresses all waste streams generated at ORNL: sanitary/industrial, radioactive, hazardous, and mixed. The Pollution Prevention Awareness Program administered by the WRP is designed to heighten employee awareness of the waste reduction initiative and to emphasize the value of each individual's contribution toward reducing waste. Table 6.4 provides the funding requirements for ORNL's Waste Minimization Plan.

ORNL is a leader among DOE facilities in the application of the National Environmental Policy Act (NEPA) process for its planning activities. Projects are reviewed to determine the applicability of NEPA. Preliminary screening identifies whether projects may qualify for a categorical exclusion or may require more detailed environmental assessments. Project managers are kept informed of the status of their projects, and a dedicated staff

Table 6.3
Tiger Team Corrective Action Plan projected funding requirements by fiscal year[a]
($ in millions)

	1993	1994	1995	Beyond
Energy Research (DOE-ER)				
Program	11,094	9,274	740	0
GPP[b]	6,410	1,000	1,000	0
GPE[c]	200	0	0	0
Line item	25,915	21,000	27,200	9,400
Environmental Management (DOE-EM)				
Program	52,432	46,265	46,799	89,668
GPP	4,400	4,000	4,000	4,000
Line item	15,900	26,500	39,100	35,000
Nuclear Energy (DOE-NE)				
Program	180	400	150	50
Defense Programs (DOE-DP)				
Program	90	0	0	0
Overhead	1,905	365	123	77
Total	118,526	108,804	119,112	138,195

[a]Costs for actions are not specifically tracked within the ORNL accounting system, and funds have not been specifically requested but are included in normal budget requests. Actual funds received have not approached these amounts.
[b]General plant project.
[c]General-purpose equipment.

Table 6.4
Waste Minimization Plan funding by fiscal year[a]
($ in millions–BA)

	1993	1994	1995	1996	1997	1998	1999	2000
ADS[b] 3203.2 (EW-30)	1.0	2.3	0.1	0.1	0.1	0.1	0.1	0.1
ADS[b] 3252.2 (EX-30)	0.6	0.7	1.06	1.1	1.2	1.2	1.2	1.3
Total	1.6	3.0	1.16	1.2	1.3	1.3	1.3	1.4

[a]Waste minimization funding is included in the Waste Management costs in Table 6.5.
[b]Activity Data Sheet.

prepares and tracks the necessary documentation. DOE personnel make the determination of the proper classification of projects and must approve all projects, but the efforts of the ORNL staff facilitate the actions of DOE.

Additional space for ES&H personnel would be provided by the proposed ES&H Compliance and Training Building. This 50,000-ft^2 building will house about 200 personnel from the various ES&H disciplines and will provide consolidated office space for them to interact and operate more effectively and efficiently. The 2-year project is currently scheduled to begin in 1996 and to cost $12.6 million.

6.2.3 • Environmental Restoration and Waste Management Activities

Environmental restoration and waste management activities at ORNL are the line responsibility of the Central Environmental Restoration Division and Energy Systems Waste Management Organization of the Energy Systems Environmental Restoration and Waste Management Programs.

The Waste Management and Remedial Action Division at ORNL handles waste management activities and serves as Facility Managers for environmental restoration sites. Funding levels for environmental restoration and waste management are given in Table 6.5.

Environmental Restoration

Several hundred sites at ORNL are contaminated with radionuclides and hazardous chemicals. These sites include inactive underground waste storage tanks, leak and spill sites, radioactive waste burial grounds, and approximately 85 contaminated facilities (including five reactors) that require remedial actions, plus significant contamination of surface water, groundwater, and biota. Multiple areas of contamination are connected within a complex geological and hydrological setting in which that plumes have mingled, so remedial activities must consider surrounding and downgradient areas.

A Federal Facility Agreement among DOE, the State of Tennessee, and the Environmental Protection Agency provides a framework for actions to protect human health and the environment, achieve compliance with environmental regulations, and meet the expectations of the public.

The remedial action component of the Environmental Restoration Program addresses the investigation and remediation of the contaminated sites and contaminated environmental media at ORNL. Environmental data are collected in cooperation with other efforts at ORNL (e.g., the Environmental Compliance Program) with support from technical staff in the Environmental Sciences Division, Energy Division, and other ORNL organizations to address contaminant transport in the complex hydrogeologic setting at ORNL. Efforts to evaluate and remediate environmental problems build on research efforts at ORNL that are supported by DOE's Office of Energy Research and other basic science programs.

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

1. Sites are prioritized for rapid actions based on human health and environmental risk. Rapid actions are taken to address contaminant releases and transport to off-site surface water and local groundwater. These must be consistent with likely future final actions. Monitoring at key locations quantifies and tracks contaminant releases and identifies major sources of contaminant release.

Table 6.5
Environmental Management planned funding by fiscal year
($ in millions—BA)[a]

	1994	1995	1996	1997	1998	1999	2000
EM Corrective Activities							
Operating	1.0	1.0	0.5	0.6	0.0	0.0	0.0
Capital equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Line item	18.0	26.1	6.0	0.0	0.0	0.0	0.0
Total	19.0	27.1	6.5	0.6	0.0	0.0	0.0
Environmental Restoration (ADS 2701 only)							
Operating	7.9	1.0	9.2	10.0	10.2	9.8	10.0
Capital equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	7.9	1.0	9.2	10.0	10.2	9.8	10.0
EM Isotope Facilities Deactivation[b]							
Operating	8.8	8.4	23.8	23.8	0.0	0.0	0.0
Line item	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	8.8	8.4	23.8	23.8	0.0	0.0	0.0
Waste Management							
Operating	55.4	52.3	57.9	58.8	62.7	60.3	61.1
Capital equipment	1.0	1.0	1.0	1.3	1.5	2.0	1.6
Construction	23.3	35.6	21.3	17.5	9.6	14.8	5.4
Total	79.7	88.9	80.2	77.6	73.8	77.1	68.1
Other[b]							
Operating	2.5	5.5	5.5	5.5	5.5	5.5	5.5
Capital equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	2.5	5.5	5.5	5.5	5.5	5.5	5.5
Total EM funding	120.9	130.9	125.2	117.5	89.5	92.4	83.6

[a]Operating BA, capital equipment, construction, and proposed construction. These estimates reflect funding from Energy Systems central organizations, excluding Technology Development (EW40).
[b]Funding included in the ORNL Financial Plan.

2. Remedial investigations are conducted to provide the information needed to formulate and implement final remedial actions. This step also includes working with stakeholders to establish land use objectives, conducting technology development activities, and performing feasibility studies.
3. Remediation is conducted to achieve the final goals for risk reduction and compliance with environmental regulations commensurate with planned or potential future land use.
4. Monitoring is continued at key locations to document the performance of remediation, evaluate the need for contingent actions, and identify remaining or new areas of concern.

Contaminated sites are prioritized for investigation and remediation on the basis of current and future risk to human health and the environment. Sites are prioritized for early actions based on potential off-site risk and for final actions based on potential future on-site risk to human health and the environment. Early actions for contaminant releases off-site have been initially prioritized on the basis of the contribution to the risk from water ingestion

at White Oak Dam. Early actions are then taken to rapidly reduce these contaminant releases. Final actions have been prioritized on the basis of future potential on-site risk. This prioritization was developed from contaminant inventories and potential hazard and the ranking was modified by the potential for off-site release or on-site exposure resulting from failure of existing containment.

Environmental restoration activities planned for FY 1995 include:

- monitoring and assessment of ORNL groundwater, surface water, and ecology,
- demonstration of a remote operated excavator for buried waste and other technologies for environmental cleanup,
- completion of a feasibility study to evaluate remedial options for radiologically contaminated surface water impoundments in the main plant area,
- completion of action to collect and treat a contaminated groundwater plume in the main plant area,
- initiation of the demonstration of technologies for removing contaminated sludge from large Gunite waste storage tanks in the main plant area,
- initiation of actions to mitigate ^{90}Sr releases from waste area grouping (WAG) 4,
- completion of actions to collect and treat ^{90}Sr groundwater seeps from WAG 5,
- completion of the in situ vitrification of contaminated soils at WAG 7, and
- removal of the liquid contents from several inactive waste storage tanks.

A number of facilities have been declared inactive or surplus because the programs for which they were built have ended. Because radioactivity could be released to the environment, these facilities are planned to undergo decontamination and decommissioning (D&D) activities. Until D&D is complete, facilities that contain substantial amounts of residual radioactive material must be kept under surveillance to schedule any necessary maintenance and to ensure containment. The inventory of surplus contaminated facilities includes experimental reactors, technology support facilities, hot cells, isotope processing facilities, research laboratories, and decontamination facilities. There are currently about 100 inactive or surplus facilities.

A special element of the program is the preparation of the ORNL isotopes production and distribution facilities for safe shutdown. The Isotopes Facilities Deactivation Project (IFDP) manages the activities required to place the facilities in a radiologically and industrial safe condition for acceptance into DOE's Environmental Restoration Program. The goal of the program is to place all 16 facilities in the program in a condition such that (1) all stored radioactive materials, high-level radioactive wastes, and contaminated liquid waste have been removed; (2) the structures and radiation-monitoring systems are in a physical condition adequate to contain and to monitor any radioactive contamination in accordance with DOE Order 5480.1; (3) security systems and procedures are adequate to prevent unauthorized entry; and (4) all hazardous chemicals have been removed. Funding and management responsibility for this program was transferred to DOE's Office of Environmental Management (DOE-EM) in FY 1994. The program budget was $8.8 million in FY 1994, with estimates of $8.4 million for FY 1995; $23.8 million for FY 1996, and $23.8 million for FY 1997. These funding levels assume that the program's waste management costs (approximately $3 million per year) are paid at the headquarters level in FY 1995–FY 1997 and not directly by the program as in previous years. As part of the transferring the program management from DOE's Office of Nuclear Energy to DOE-EM, DOE-EM commissioned an independent technical review of the program in the first quarter of FY 1994. A major recommendation of the review was that the management of the program be transferred into the Energy Systems

Environmental Restoration and Waste Management organization. This transfer was initiated in the second quarter of FY 1994. A revised program plan has been developed for the IFDP.

To meet the objective of adequate containment and site control, a structured program of surveillance and maintenance (S&M) has been established. The objectives of the S&M program are to ensure adequate containment of residual radioactive and hazardous materials, to provide safety and security controls to minimize potential hazards to on-site personnel and the general public, and to cost-effectively manage surplus sites and facilities in compliance with applicable DOE Orders. These objectives are met through a structured program of periodic surveillance and site inspections, routine maintenance, and special projects beyond a routine nature to correct facility degradation or to eliminate facility-specific hazards.

The budget for decommissioning of surplus facilities is highly variable and is subject to annual reprioritization by DOE. D&D projects are implemented according to priorities set at the national level by the DOE Environmental Restoration Program. Budget requests for decommissioning of prioritized facilities at ORNL are submitted annually and included in the DOE Environmental Restoration and Waste Management Five-Year Plan. Priorities are then ranked with facilities and sites from other DOE installations, and budgets are allocated accordingly. Projects are implemented by the ORNL Remedial Action Program in accordance with these budget allocations. The budget for decommissioning surplus facilities is approximately $7.9 million in FY 1994. Subsequent annual budgets are expected to increase significantly during the planning period to keep pace with DOE's goals for site restoration. Near-term D&D projects will focus on removal of facilities in conjunction with regulatory-driven remediation of former waste management sites.

Waste Management

The waste management program at ORNL provides continuous collection, treatment, and discharge of gaseous wastes; treats 570 million liters (150 million gal) per year of liquid radioactive waste (excluding sewage); and manages about 70,000 m^3 (750,000 ft^3) per year of solid radioactive, hazardous, mixed, and sanitary/industrial wastes. Major waste management activities include comprehensive coordination of waste reduction; integrated strategic and long-range planning; upgrades of existing facilities and construction of new ones; performance assessments of solid waste storage areas and other waste disposal facilities; waste collection and certification; and waste treatment, storage, and disposal.

Expense funding for waste management activities in FY 1994 is about $60 million, including $1.6 million for waste minimization (see Tables 6.4 and 6.5). The corrective activities component of the expense funding provides for implementation of the Federal Facilities Agreement (FFA) requirements as they pertain to active low-level liquid waste (LLLW) tanks and tank systems. It also includes upgrades of the Bethel Valley and Melton Valley LLLW collection and transfer systems. Proposed line item projects include three projects for implementation of the active LLLW tank systems requirements of the FFA, one project for construction of the Melton Valley Storage Tanks Capacity Increase Project, and one project for the Process Waste Treatment Facility.

Out-year activities in waste management include continued operation of waste treatment, storage, and disposal facilities, with many major upgrades. Additional reservation-wide facilities for waste management will be added to promote efficiency and improved ES&H conditions. Waste reduction will continue to be emphasized.

6.3 • Management Practices

6.3.1 • Site and Facilities Planning

ORNL's programs create demands for a variety of building and equipment needs, including specialized experimental laboratories, a large complement of office space, and major utility and waste disposal facilities. ORNL occupies ~2.6 million ft^2 of building space at the main Bethel Valley site and the Melton Valley site to the south, over 1 million ft^2 of building space at the Oak Ridge Y-12 Plant, and ~200,000 ft^2 of space at the Oak Ridge K-25 Site. Space distribution and use are described in the Appendix (see Figs. A.1–A.7 and Tables A.1 and A.2).

ORNL carries out site and facilities development planning with the objectives of providing high-quality space, reliable utility support, and the additional necessary infrastructure required to produce the appropriate environment for conducting outstanding research on DOE programs. To achieve this goal, capital assets planning is closely coupled to the Laboratory's technical program objectives and plans as described in this document. The ORNL Integrated Facilities Plan is summarized in Sect. 7.

A major new project is proposed to allow extensive renovations and rehabilitation of general-purpose buildings and utility systems that have deteriorated owing to insufficient capital improvement funding for modernization and adaptation to changing program needs. This facilities restoration project (which does not include environmental restoration and waste management needs) would continue throughout the planning period and into the period ending in 2010. The multiprogram general-purpose facilities section of Table A.3 shows specific line-item requests supporting this initiative.

This initiative will be supplemented with a vigorous program to manage and ultimately to renovate or dispose of facilities that have exceeded their useful life and that require continual surveillance and maintenance to ensure safe shutdown. These inactive facilities include obsolete research reactors, former isotope production facilities, and former biological research facilities. We anticipate eventual elimination of the inactive reactor and isotope facilities as part of DOE's Decontamination and Decommissioning Program.

6.3.2 • Information Resource Management Planning

ORNL increasingly recognizes the importance of information generated and used by all staff members. Timely and reliable information is critical to meeting mission objectives. The need for effective management of the large volume of information throughout ORNL has become vital. Steps are being taken to strengthen management attention to information as an asset and to improve user involvement in the effective utilization of information resources.

The management of information resources spans many areas—computing, telecommunications, records management, scientific and technical information, and printing and publishing. ORNL's specific vision of the future includes building on the new opportunities apparent in working with industry and the education community to complement traditional computational science efforts. Supporting technologies—including gigabit networking research, multiterabyte storage technology, software development for massively parallel processors, visualization, and algorithm development—will be key focus areas in the future. Specific ORNL highlights and plans in these information resource management (IRM) areas

are detailed in the *Strategic Plan for Computing at Oak Ridge National Laboratory*, ORNL/PPA/INT-94/2, which is summarized in Sect. 7.

The continued development of a company-wide IRM program is a top priority for Energy Systems. Major steps in this development occurred with the announcement of a Corporate Information Officer. This announcement also called for the creation of a Corporate Information Management Steering Council, composed of high-level representatives from the IRM service providers and each of the major Energy Systems business units, including ORNL, to guide the evolution of the program. The combined efforts of this Steering Council will coordinate the efficient sharing of resources across all of Energy Systems. In the near term, benefits are expected to be realized by eliminating duplication of effort. Specific IRM plans are detailed in two documents: the *Martin Marietta Energy Systems FY 1996 Information Resources Management Site Plan*, K/CSD/INF-94-1, and the *Martin Marietta Energy Systems Information Resources Management Strategic Plan*, ES/ESH-39, which are summarized in Sect. 7.

6.3.3 • Total Quality Management

ORNL developed a view of quality through an internal assessment in 1992. This view was formalized in a brochure, *Total Quality Management at ORNL*, that was distributed to all ORNL staff members. A formal Quality Assurance (QA) Program applies to all activities conducted by or for ORNL. This program incorporates planning for prevention of problems, quality control to assure conformance to requirements, and continuous performance improvement. Independent audit functions verify compliance with QA requirements and evaluate the effectiveness of QA programs. Self-assessments are conducted to evaluate performance and identify areas of improvement.

Within the Operations, Environment, Safety, and Health Directorate, the Office of Quality Programs and Inspection is organized into four sections. The QA Section is responsible for the interpretation of DOE Order 5700.6, "Quality Assurance," and develops procedures and systems for its implementation. QA specialists are assigned to line organizations to assess them in planning and implementation and to verify adherence to management control systems. The Quality Reporting and Technical Service Section develops, implements, administers, and reports on the ORNL Occurrence Reporting Program, the ORNL Management Indicators, and the Quality Office Training Program. The Quality Engineering and Inspection Section provides surveillance of in-service equipment and new construction. The Laboratory Assessment Program manages and coordinates all assessment activities at ORNL, with emphasis on evaluations management, technical audits, corrective action management, and continuous improvement, with the goal of establishing a program of continuous self-assessment and self-improvement that is verified by a coordinated and integrated system of internal and external oversight. ORNL has also identified an individual point of contact for continuous improvement.

These programs support ORNL managers in the implementation of programs that foster effective R&D, accomplish ES&H objectives, and meet quality requirements.

6.4 • Communication and Trust

ORNL has made improved responsiveness to internal and external stakeholders one of its strategic goals (see Sect. 2.2.6). Strategies for achieving this goal have been identified and are being implemented. These include encouraging employee empowerment and including effective communication with employees as a measure of performance for managers. The needs of the public for information are being addressed through activities such as the creation and distribution of a videotape about ORNL, the second ORNL Community Day in June 1994, support for DOE's efforts to find and release information pertaining to human experiments, and a growing effort to make ORNL's information resources available electronically (see Sect. 7.3.1). A recent activity that supports the Laboratory's goal is the establishment of a satellite center of the Oak Ridge Recording for the Blind unit in ORNL's Central Research Library. This facility provides access to a pool of technically trained volunteer readers and will enhance the production of scientific and technical materials for the visually disabled.

7 • Summaries of Other Plans

7.1 • Technology Transfer Plan

ORNL's technology transfer plan supports DOE's emphasis on partnerships. Technology transfer efforts at the Laboratory are a key component of the Martin Marietta Energy Systems, Inc., technology transfer program, which focuses the resources of DOE's facilities in Oak Ridge on the technological challenges facing U.S. industry.

7.1.1 • Vision

The ORNL technology transfer program will set the standard for technology transfer from federal laboratories.

7.1.2 • Strategic Objectives

- The engineering and applied science infrastructure of ORNL, which has deteriorated with the decline of large programs, will be revitalized. A strong engineering and applied science base is an essential part of establishing and maintaining strong ties with industry.
- A vigorous personnel exchange program, including senior management, will be undertaken with industry to increase awareness in our staff of the industrial perspective and to acquaint industry with our capabilities.
- The development of specialized user centers having broad appeal to industry will be undertaken. Experience with the High Temperature Materials Laboratory demonstrates that access to moderately expensive and sophisticated laboratory equipment enhances competitiveness and attracts industry to the area.
- The role of ORNL in the Regional Assistance Program will be expanded.
- Strategic alliances with other national laboratories, industrial consortia, and universities will be expanded to provide stronger ORNL participation in major national initiatives.
- The ORNL program will be highly innovative. Appropriate metrics will be developed and tracked to refine our approach to existing activities.
- Legal and bureaucratic barriers will be eliminated to increase university and industrial participation in the full range of our programs.

7.1.3 • Resources and Staffing

The resources and staffing needed to implement Energy Systems technology transfer plans are listed in Table 7.1.

Table 7.1
Technology transfer effort
Estimated expenditures and staffing by fiscal year for the Office of Technology Transfer[a]

	1993[b]	1994	1995	1996	1997	1998	1999	2000
	Funding ($ in millions—BA)							
ORTA[c] activity	2.88	2.58	2.68	2.71	2.82	2.93	3.05	3.17
Patent/licensing activity	1.12	1.24	1.27	1.30	1.35	1.41	1.46	1.52
CRADA[d] funding								
Federal	16.34	39.00	53.80	79.90	83.10	86.42	89.88	93.47
Private industry	1.56	8.60	16.16	42.02	43.70	45.45	47.27	49.16
In kind[e]	18.62	44.46	61.33	91.09	94.73	98.52	102.46	106.56
Total	40.52	95.88	135.24	217.02	225.70	234.73	244.12	253.88
	Professional staffing [full-time equivalent (FTE) employees]							
ORTA activity	25.1	25.6	26.0	26.0	26.0	26.0	26.0	26.0
Patent/licensing	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8
CRADA activity	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Total	37.9	38.4	38.8	38.8	38.8	38.8	38.8	38.8

[a]Data are for the Office of Technology Transfer, Martin Marietta Energy Systems, Inc., which includes ORNL, the Oak Ridge Y-12 Plant, and the Oak Ridge K-25 Site.
[b]Actual.
[c]Office of Research and Technology Applications.
[d]Cooperative research and development agreement.
[e]Estimated.

7.1.4 • Patents and Licensing

The Office of Technology Transfer will continue to build on its successful efforts in patenting and licensing new technologies. Licenses executed in FY 1993 are listed in Table 7.2. Patent and licensing projections are presented in Table 7.3.

7.2 • Site and Facilities Plans

The ORNL Integrated Facilities Plan (IFP) defines ORNL's plans for facilities and site development.* In addition, it serves as a reference source for a broad base of site and facilities characterization data. It is responsive to two DOE Orders directed at the management of government assets: DOE 4320.1B, "Site Development Planning," and DOE 4320.2A, "Capital Asset Management Process." The IFP also responds to a DOE memorandum, "Guidance for Preparation of the 1994 Laboratory Integrated Facilities Plan," January 31, 1994.

*_ORNL Integrated Facilities Plan_, ORNL/PPA-94/2, Martin Marietta Energy Systems, Inc., April 1994. Also available on CD-ROM.

Table 7.2
Licensing summary
(October 1, 1993)

Technology	Licensee
Check valve monitoring	B&W Nuclear Services, Inc.
Alpha scintillator detector	Radiation Instrument Specialists Corp.
Motor current signature analysis	Intelligent Sensors, Inc.
Atmospheric sampling glow discharge ionization system	Ion Systems Technologies, Inc.
Ion trap mass spectrometry	Ion Systems Technologies, Inc.
Apparatus for weighing and identifying characteristics of a moving vehicle	International Road Dynamics
Nongraphite crucible for high-temperature applications	Blasch Precision Ceramics
Lead-stabilized superconductor precursors	Superconductive Components
Infrared PCB mass spectral data	Texas Engineering Experiment Station
Cryoblasting process	Cryogenic Applications F, Inc.
Nonhazardous solvent for cleaning metal surfaces	Abrasive Belt Master
Respirator fit test data	TSI, Inc.
PNEU-WORM robot	Remotec, Inc.
Lid design for low-level waste container	Brainard Associates, Inc.
Damage-tolerant light-absorbing material	Aerospace Enterprises, Inc.
Sample inlet technology	Teledyne Electronic Technologies
Ion source	Teledyne Electronic Technologies

The DOE Multiprogram Energy Laboratories Facilities Support (MEL-FS) program provided $114,000 in FY 1994 to support capital assets management and planning (CAMP) activities at ORNL. This funding is expected to continue.

The IFP is structured around a site development planning analysis required by DOE Order 4320.1B. It summarizes ORNL's present missions, programs, and population; reviews regional conditions; and describes site assets (land, buildings and other structures, utility distribution systems, transportation infrastructure, security and safety systems, and waste management systems). An inventory of existing assets, categorized according to the CAMP Functional Unit Breakdown Structure, is provided. The construction projects required to support ORNL's future mission and program plans are described, and the impacts of these projects on the site's assets are summarized. Key elements of the site planning analysis are presented: assumptions and objectives for site development, and evaluation of the site for each objective, and alternatives for removing each site's deficiencies or excesses. A Master Plan for the site, with a 20- to 30-year time frame for full implementation, is developed and described. A review of the anticipated status of the site in ten years is presented to illustrate how the Master Plan is to be implemented. Key elements are summarized here.

Table 7.3
Patent and licensing projections[a]

	FY 1993[b]	FY 1994	FY 1995	FY 1996	FY 1997
Patent applications	79	79	82	85	88
Patents granted	27	41	41	42	44
Product sales (in thousands of dollars)	21,780	13,999	15,600	20,300	28,400
Number of new licenses	17	22	24	27	29
License income (in thousands of dollars)	376	500	1,000	1,500	2,000
Use of income (in thousands of dollars)					
Employee awards	101.5	135.0	270.0	405.0	540.0
ORTA[c] office support	115.3	113.4	392.5	557.5	722.5
Other Lab R&D support	142.5	150.0	187.5	312.5	437.5
Federal income taxes	16.7	41.6	50.0	75.0	100.0
Technology transfer memberships	0	60.0	100.0	150.0	200.0

[a]Funds are for the Office of Technology Transfer, Martin Marietta Energy Systems, Inc., which includes ORNL, the Y-12 Plant, and the K-25 Site.
[b]Actual.
[c]Office of Research and Technology Applications.

7.2.1 • Facilities Planning Process

Future facility and land requirements are determined by future mission and program plans and by the functional and physical adequacy of existing facilities and equipment. CAMP provides a systematic approach to the management of government capital assets and is implemented through a structured, year-round program that includes asset surveys, evaluation, and prioritization of needs so as to produce an annual long-rage asset plan for the site.

In its fully implemented form, CAMP relies on input from a formal Condition Assessment Survey (CAS), which is entered into a Condition Assessment Information System (CAIS). In addition to providing automated support for CAS, CAIS is to incorporate input from other inspection programs, such as OSHA inspections and safety reviews. CAIS provides the maintenance and repair information needed in developing a budget that covers the entire life cycle of each capital asset. This budget is called an Asset-Level Life Cycle Plan.

ORNL plans to implement a computerized interactive life cycle planning capability, accessible by all facility managers, as its CAIS. Using CAIS and planning information specific to each facility, facility managers will update Asset-Level Life Cycle Plans as new information becomes available. These plans will be integrated annually (or as needed) to produce the Functional Unit Life Cycle Plans required for CAMP.

7.2.2 • Master Plan and Ten-Year Facility Plan

In preparing the Master Plan, ORNL uses two budget scenarios for the multiprogram general-purpose line-item projects needed to achieve planning goals and listed in Table A.3:

(1) funding is not a limitation, and (2) funding is limited to $15 million per year, so that projects must be prioritized. Priorities are assigned as follows:

- Priority 1: projects that provide for the safety and health of employees, visitors, and the general public with regard to correcting existing structural, mechanical, electrical, and environmental deficiencies.
- Priority 2: projects that provide for the repair and rehabilitation of existing facilities.
- Priority 3: projects that provide engineering design and construction services for those facilities which require modifications or additions in order to meet the needs of new or expanded programs.

Under scenario 1, all projects are complete and the facilities revitalization goals that they represent are achieved in FY 2002. Under scenario 2, this date slips to FY 2022. Project deferral imposes a cost penalty: the longer refurbishment is put off, the more deterioration occurs. Additional funding will be required to correct this additional deterioration. Under scenario 2, the backlog of projects will climb to nearly $248.5 million by 2005, not counting additional costs due to deferral.

7.2.3 • Maintenance Plans

Overhead and programmatic funding for maintenance activities is expected to remain constant in real terms. A substantial fraction of the requested funding will be applied to industrial training upgrades, maintenance job and task analysis, compliance with DOE Order 4330.4A, infrastructure improvements, asbestos surveys, and condition assessment surveys. A portion of ORNL's maintenance expenditures will be applied to corrective maintenance jobs that have been requested but not yet performed and preventive maintenance that is past due. Eliminating the backlog of corrective maintenance jobs will cost an estimated $1.4 million; the backlog of preventive maintenance, an estimated $300,000. Eliminating the maintenance-related backlog in such areas as services, betterments, improvements, and modifications (which does not include preventive and corrective maintenance) would cost approximately $8.8 million.

7.2.4 • Capital Equipment Funding Plans

Capital equipment can be categorized according to the broad purposes for which it is used. At ORNL, two categories are used: capital equipment for research programs, and general-purpose equipment (GPE).

The annual funding requested by ORNL to meet research program needs is $25 million to $30 million. ORNL typically receives $18 million to $20 million. This is at most 80% of the amount deemed necessary to meet the goals of the Laboratory's research programs.

GPE support is the only source of funds for supplying the Laboratory's support and service divisions with capital resources. Items typically procured with GPE funds include storage tanks, shop and maintenance equipment, personnel and environmental monitoring equipment, computers, test equipment, security and fire protection needs, and other items related to the general operation and upkeep of ORNL. ORNL has relied heavily on receipt of these funds to provide critical replacements. However, for many years, the GPE funding level has been insufficient to maintain a modern research facility. ORNL has historically received about $3 million annually for GPE out of the $10 million to $15 million considered

necessary. While GPE funding of $5.6 million was provided in FY 1994, ORNL is experiencing an equipment request backlog exceeding $14 million for FY 1994. Items not funded in FY 1994 are still required and thus have been added to the FY 1995 funding request of $10 million.

In addition to the continuing need for multiple-use GPE funding, there are two areas of special importance. First, health physics instruments must be upgraded as a required Tiger Team corrective action. The MEL-FS program has provided capital equipment funds for this activity ($200,000 in FY 1993 and $185,000 in FY 1994). Additional funding is needed. Second, chlorofluorocarbon (CFC) replacements, estimated at $20 million, are required because the Clean Air Act with Amendments phases out production of Class 1 refrigerants by December 31, 1995. Most of the compressor equipment used in cooling systems contains CFCs; some of this equipment cannot be converted to other refrigerants and will have to be replaced. A schedule has been developed for complying with the date by which CFCs must be phased out; however, it is contingent on funding.

7.2.5 • Inactive/Surplus Facilities Plans

A large number of facilities at ORNL are currently inactive or surplus, or are expected to become so in the next several years. These facilities are either no longer needed for their original purpose or are old and deteriorating to the point that continued upkeep as operational facilities is not cost-effective. A large portion of these facilities are also contaminated with radioactive or hazardous materials and have no programmatic support from DOE. At present, the expense of surveillance and maintenance for these facilities is borne primarily by division or Laboratory overhead. See Sect. 6.2 for descriptions of some of these activities.

The newly established Inactive and Surplus Facilities Program (KG03) within the MEL-FS program provided $155,000 in FY 1994 to demolish a retired greenhouse (Bldg. 9982). Similar projects for removal of facilities with little radiological or chemical contamination will be funded by this subprogram during the planning period.

7.3 • Strategic Plan for Computing

The *Strategic Plan for Computing at Oak Ridge National Laboratory* (ORNL/PPA/INT-94/2, September 1994) describes ORNL's plans for computational science and the use of computing tools. A summary is presented here.

7.3.1 • Vision and Strategies

ORNL's overall vision in computing is to become a premier center for computational science, where computational scientists desire to work, and where outreach to industry and education are central themes. Access to and manipulation of information on the desktop will become so easy that the computer will become the primary office tool for all ORNL staff.

To realize this vision, several long-term strategies have been identified. These strategies are organized into five areas: collaborations, computational sciences, high-performance computing and communications (HPCC) technologies, services, and user platforms.

Collaborations

Industry: ORNL will be a major partner with industry in projects that effectively transfer computing-related technologies to the private sector.

Education: While continuing its traditional strong involvement with undergraduate, graduate, and postgraduate education, ORNL will address lifelong learning through a focus on programs in education for students in kindergarten through high school.

Computational Sciences

In order to become a premier center for computational science, ORNL will focus on a few computational areas where it can build on existing strengths. The problems to be addressed will, in the main, be Grand Challenges, and emphasis will be placed on collaborative projects with, and in support of, industrial partners.

HPCC Technologies

ORNL will provide state-of-the-art HPCC support technologies to create a research ambiance to support the achievements of Grand Challenge computational science groups.

Computer hardware: ORNL will maintain its current leading position in obtaining high-performance research systems, developing systems, and production systems.

Data storage: ORNL will build on both current and planned storage experiments and systems to remain at the forefront of storage technology. ORNL will collaborate with industry and with other DOE laboratories in the use of these resources and this expertise.

Network research: ORNL will always have at least three technologies in the development queue: a research-level technology, a near-commercial technology, and a production-quality technology.

National Information Infrastructure (NII): ORNL will be a leader in the deployment of information infrastructure technology in the manipulation of large datasets, in collaboration with research partners, and in its daily research environment.

Algorithms: ORNL will be at the forefront in the development and analysis of numerical algorithms for solving large-scale scientific and engineering problems on advanced computer architectures. Emphasis will be on the transfer of this algorithmic technology to applications such as high-level interfaces and/or integration into software libraries.

Informatics: ORNL informatics research and development will expand significantly beyond the initial and continuing focus on genome informatics to address fundamental and applied problems in intelligent information processing.

Software tools: ORNL will continue to build on its world-wide reputation for developing quality software tools such as Parallel Virtual Machine (PVM), while expanding the scope of generically useful tools being developed, such as those for using large datasets.

Visualization: ORNL will stay at the cutting edge of this fast moving field, both in the development of emerging visualization technologies and in their application across computational disciplines. This will necessitate more attention to this field than has been given in the past.

Services

Information resource management (IRM): ORNL will have a coordinated program in which all ORNL staff have access to the information they need, when they need it, without concern for the source or the logistics of the information flow.

Production systems: Corporate administrative and operational information will be provided to users on their desktops in a user-friendly, client/server form based on open systems standards. Production UNIX environments will be available for scientific and technical computing users who do not have the necessary resources within their divisions.

Production networks: ORNL intends to continue to provide a high-speed fiber-optic backbone and connections to the Internet. Bridges, routers, network monitoring, and name-service are provided. Services are provided to allow users to easily connect to this infrastructure via Ethernet or better.

Information servers: ORNL staff will have desk-top computer access to management, compliance, scientific, engineering, and marketing information in immediately accessible, searchable, standard electronic form. Information server software to be used by a large population of clients should be designed with input from the user population. Seamless systems should be in place to allow for all ORNL employees to publish and provide electronic information that is accessible to computer users internal and external to Martin Marietta Energy Systems, Inc.

User Platforms

ORNL will modernize its desktop computing and networking hardware and software to reduce overall cost and to facilitate information access and exchange.

7.3.2 • Goals

The following specific goals that support the vision and strategies in Sect. 7.3.1 are defined in the *Strategic Plan for Computing at Oak Ridge National Laboratory.*

Strategic area **Collaborations**

Focus area **Industry**

Goal 1. Computational Center for Industrial Innovation (CCII) industrial interactions: Provide a hardware/software/collaborative environment through the CCII such that there are more than 12 industrial members by FY 1996.

Goal 2. American Textile Partnership (AMTEX) cooperative R&D agreement: Demonstrate usage-driven manufacturing and replenishment of textile supplies for health care delivery applications. Demonstrate access, filtering, analysis, and effective feedback of point-of-sale information into the textile industry supply chain.

Goal 3. Transportation collaborations: Establish a collaborative research environment in human-computer interactions for intelligent transportation systems. By FY 1996, establish collaborations in this area with at least six industry representatives.

Goal 4. Gas and Oil NII collaboration: Achieve production runs of Institut Français du Petrole seismic model on the Intel XP/S 35.

Strategic area **Collaborations**

Focus area **Education**

Goal 5. CU-SeeMe experiment: Use CU-SeeMe to allow a researcher at ORNL to give an interactive demonstration to up to eight remote sites via the Internet.

Goal 6. Expansion of Adventures in Supercomputing (AiS) to middle schools: Select at least three middle schools for participation in AiS.

Strategic area **Computational sciences**

Goal 7. Materials: Develop tight-binding molecular dynamics production code for >2000 atoms with application to the phase diagram of carbon. Port large-scale ab initio pseudopotential production code to Intel XP/S 35 with applications to metallic systems. Implement full-potential large-system multiple scattering method and produce production code for the XP/S 35.

Goal 8. Groundwater: Incorporate into GCT code two-phase flow with relative permeabilities, additional chemical reactions, three-phase flow with relative permeabilities, and simple mass transfer between phases and components.

Goal 9. Computer Hardware, Advanced Mathematics, and Model Physics (CHAMMP): Attain a high-resolution ("T170") climate simulation run covering 3 years with the PCCM2 code.

Strategic area **HPCC technologies**

Focus area **Computer hardware**

Goal 10. Massively parallel processing (MPP) upgrades: Bring the Intel Paragon XP/S 150 successfully through acceptance testing and into production, with application code performance consistent with machine capabilities.

Focus area **Data storage**

Goal 11. High-performance storage system: Install the parallel storage system HPSS as the controller for the ≈100-terabyte Center for Computational Sciences/Atmospheric Radiation Measurement storage environment in FY1995.

Focus area **Network research**

Goal 12. Establish an ongoing research effort aimed at supporting the leading edge of production network technology and (through protocol development and similar research) complementing ORNL research in MPP computation.

Focus area **National Information Infrastructure**

Goal 13. Secure funding for one additional NII technology project.

Focus area **Informatics**

Goal 14. Bioscience: Develop tools for federation of biosciences databases.

Goal 15. Healthcare: Develop and evaluate intelligent tools for information processing and decision support in health care delivery applications.

Focus area **Software tools**

Goal 16. MPP software development: Establish four specific software development projects in FY 1995 with Intel and Kendall Square.

Focus area **Visualization**

Goal 17. Visualization research: Demonstrate a data-distributed visualization of a salt dome seismic dataset.

Goal 18. Coordination of visualization activities: Improve lab-wide communication/coordination of visualization activities through formation of an ORNL visualization steering group and through improved benchmarking with other national laboratories, universities, and research centers. Hold quarterly seminars to demonstrate new and existing visualization capabilities at ORNL.

Strategic area **Services**

Focus area **IRM**

Goal 19. Information to the desktop: Acquire or develop tools, techniques and applications that support the information needs of ORNL.

Goal 20. Energy Systems corporate applications: Ensure maximum participation in deployment of corporate applications to enable appropriate implementation for ORNL.

Focus area **Production systems**

Goal 21. General-purpose MPP system: Acquire and put into production a high-performance, parallel, stable system for use by ORNL researchers.

Goal 22. Open systems: Continue to move rapidly to production open systems compliant with de facto industry standards.

Focus area **Production networks**

Goal 23. Fiber-optic network extension: Install fiber from the existing fiber-optic backbone to major concentrations of users and systems. Develop an implementation plan for providing fiber to the desktop for all ORNL technical staff.

Focus area **Information servers**

Goal 24. Financial tools: Implement prototype financial tools for ORNL. These should be user-friendly, client/server implementations that allow project managers to obtain timely, accurate, and understandable financial data.

Strategic area **User platforms**

Goal 25. Upgrade to minimum user platform:

- Hardware: graphical user interface (GUI)–compatible desktop systems.
- Network connection: Ethernet, fiber (FDDI), or better.
- GUI: Microsoft Windows, Macintosh OS, or X Windows.
- Mail: Standards-based desktop mail (MIME-compliant) system such as Eudora or Pine.
- Software: Software and applications that are either market commodities or based on vendor-neutral standards. All staff should have World Wide Web, Gopher, Whos, Telnet, ftp, and NetNews.

7.4 • Information Resource Management Plans

7.4.1 • Energy Systems Information Resource Management Plan

Martin Marietta Energy Systems, Inc. (Energy Systems) has recognized the value of its information resources and is committed to the development of an effective and efficient information resource management (IRM) program. Information resource support functions within Energy Systems represent a significant annual investment. The management of this investment receives the same considerations as that given to employees, facilities, materials, and other valuable company resources.

7.4.1.1 • Overview of IRM at Energy Systems

The "big picture" of IRM within Energy Systems is defined within the framework provided by the Energy Systems Business Model. The Business Model, which describes Energy Systems from the specific perspective of information management, is based on a comprehensive function model capturing the activities of the company and identification of the major elements of information required for those activities to be performed. Relationships between functions and information are documented, and the business functions are divided into groups, called business areas, based on information usage. The model establishes ownership for business functions and information by the appropriate Energy Systems Vice President.

The concept of business areas enables the planning of corporate databases and information systems within each business area and the sharing of information across business areas. Each business area owner will appoint an information resource steward who will work with the Classified Computer Security Program and the Technical Security Office to ensure that business area information is available, correct, and provided only to appropriate personnel. For new information systems projects, this security interface will begin during or before the requirements development phases of the project.

The Business Model is used within the IRM Site Plan to associate IRM activities with a specific program or site infrastructure support function using the business area groupings. To provide a complete framework of the total business functionality of Energy Systems, descriptions of all business areas are included in this plan. Some business areas will not have IRM activities reported at this time. As the Energy Systems IRM program grows and matures, a more complete list of IRM activities will be documented in this and future plans.

7.4.1.2 • Current IRM Environment

Each business area provides IRM oversight with links to IRM support organizations. The oversight of the Research and Technology Application area is performed at ORNL by the newly established Directorate for Computing, Networking, Informatics and Education, which includes the Center for Computational Sciences, the Computing Applications Division, the Engineering Physics and Mathematics Division, the Office of Laboratory Computing, and the Office of Science Education Programs and External Relations. Two committees provide general direction for ORNL—a User Advisory Committee in areas of scientific computing and an Administrative Computing Steering Committee for administrative computing.

Scientific computing application support for ORNL is primarily provided by the Computing Applications Division.

In FY 1993, an Information Management Task Team (IMTT), with representatives from each major functional area within Energy Systems, was formed to evaluate and target opportunities to achieve significant efficiency and effectiveness improvements through the use of applicable information management processes and technologies. In January 1993, the IMTT sponsored the development of a company-wide IRM Strategic Plan (IRM/SP) vision as part of the long-term information management convergence process. The IMTT also sponsored the development of the Technical Architecture Specification for Energy Systems.

7.4.1.3 • Vision

Improved IRM is seen as a key to the future success of Energy Systems to enable:

- survival in the midst of a changing customer mix and increased competition,
- significant improvements in efficiencies and cost savings needed owing to declining budgets, and
- leveraging of multidisciplinary expertise across sites to meet new customer demands.

The development of the IRM/SP represents a focal point for the development of the Energy Systems IRM program. Under the direction of the Corporate Information Officer and the IRM Steering Council, the IRM/SP is expected to evolve and mature in response to changes in the business and information requirements and to improvements in applications development techniques and advances in information technologies. The IRM/SP is summarized in Sect. 7.4.2.

7.4.2 • Energy Systems IRM Strategic Plan

Like other businesses, Martin Marietta Energy Systems, Inc., has experienced a rapid rise in the quantity of information generated and used by workers at every level of our operation. Success in nearly every phase of our business has become dependent upon our ability to effectively process the volumes of data provided or produced, extract from it the relevant information needed for effective decision making, and create intelligent schemes for maintaining records that validate past operations and form a basis for future plans. Information is an important company resource. Our ability to gain and use information affects our current and future operations in the same way as information affects other assets (e.g., personnel or facilities).

The IRM/SP creates a focus that will enable information to be shared horizontally across the company. This focus will support the key Energy Systems business objective to become a more integrated ("one enterprise") company. To be successful, the Energy Systems IRM program will seek to achieve an appropriate balance between integrated, company-wide information solutions and the freedom necessary to effectively meet programmatic needs. The program will emphasize the importance of providing flexibility for rapid and precise response to customer information needs. Implementing the IRM program will accrue the following benefits:

- improved performance and reduced costs,
- enhanced ability to perform existing work and to compete for new business, and
- leveraged existing information resources.

The primary objective of this program is to exploit information resources (i.e., information, applications, and information technologies) so that Energy Systems produces quality products and services as efficiently and as effectively as possible. The strategy to accomplish this objective is to share information resources across the company whenever this is cost-effective.

The IRM/SP includes a situation assessment that states the current environment and the business opportunity for developing a formal IRM Program. This assessment is followed by strategy and implementation considerations necessary to IRM program development.

Recommendations are made that highlight the activities needed to begin development of the program and the evolution toward a shared information resources environment for Energy Systems. The IRM/SP is expected to evolve and mature in response to changes in the business and information requirements, as well as to improvements in applications development techniques and advances in information technologies. As such, the plan will be reviewed and updated regularly.

7.5 • ES&H Implementation Plan

In August 1993, Energy Systems published the *Environment, Safety, and Health Strategic Plan*, ES/ESH/INT-2, Revision 1. This plan outlines goals, objectives, and strategies to be used in achieving the goals. Because tasks and work assignments are different at the different Energy Systems sites, each site requires a tailored implementation plan.

The *Oak Ridge National Laboratory Environment, Health, and Safety Implementation Plan*, ORNL-6801 (March 1994), addresses each of the goals and objectives of the Energy Systems plan and establishes action items within each of the Energy Systems strategies. Responsibilities for actions are identified in the plan.

Line managers are responsible for incorporating the implementation plan into their organizations. Compliance staff provide regulatory interpretation, guidance, and support to ensure that ES&H goals are pursued while minimizing adverse impacts to the line organizations. Laboratory Associate Directors with oversight for research are charged with conducting an annual review of each division's ES&H tasks with the Laboratory Director and the ORNL Environment, Safety, Health, and Quality Committee to ensure that overall ES&H goals are being addressed.

The implementation plan attempts to integrate the concepts of Total Quality Management into ES&H tasks. Teamwork within and between organizations is viewed as an essential component in accomplishing ES&H goals. Many of the objectives (e.g., waste minimization, radiation exposure reduction) are aimed at continuous improvement through progressive goals.

The approach used in the plan is to identify (1) the organizational level with responsibility for each task, (2) the relative ES&H priority of each task, based on regulatory requirements or potential safety and/or environmental consequences; (3) the estimated cost of each task, ranked as low (less than $50,000), medium ($50,000 to $250,000), or high (more than $250,000); and (4) the estimated time for completion, ranked as near-term (less than 1 year), mid-term (1–3 years), or long-term (more than 3 years). Where appropriate, a rationale is provided for the selection of the task.

The implementation process is summarized as follows.

- Organizational units review each task for applicability to their operations.
- Organizational units incorporate applicable tasks into the division (or appropriate organizational) safety or self-assessment plan.
- Mid- and long-term tasks are evaluated and prioritized on the basis on ES&H consequences and cost of implementation. Each organizational unit is expected to develop an abatement strategy with actions and schedule that are realistic in terms of financial constraints and ES&H priority.

8 • Resource Projections

The Laboratory's organization chart appears in the Appendix. Resource projections are presented in the following tables:

- Table 8.1, Laboratory funding summary,
- Table 8.2, Laboratory personnel summary,
- Table 8.3, funding by assistant secretarial level office,
- Table 8.4, personnel by assistant secretarial level office,
- Table 8.5, resources by program,
- Table 8.6, subcontracting and procurement, and
- Table 8.7, small and disadvantaged business procurement.

Tables 8.1, 8.3, 8.5, and 8.7 present resource projections for budget authority (BA) funding in millions of dollars. These resource projections reflect new BA funding requested in the FY 1995 budget submission documents, adjusted to incorporate any interim guidance. New BA requests are calculated by adding estimates of outstanding commitments and pre-financing to the total cost and then subtracting the prior-year uncosted budget.

Subcontracting and procurement funding is reported in Table 8.6 as total obligated funds for each fiscal year.

Personnel statistics reported in Tables 8.2, 8.4, and 8.5 are given as the number of full-time equivalent (FTE) employees.

Table 8.1
Laboratory funding summary by fiscal year
($ in millions—BA)

	1993	1994	1995	1996	1997	1998	1999	2000
DOE effort	508.5	494.6	572.2	605.8	628.7	631.3	631.3	631.3
Work for others	75.6	73.8	77.5	78.7	78.7	78.7	78.7	78.7
Total operating	584.1	568.4	649.7	684.5	707.4	710.0	710.0	710.0
Capital equipment	29.4	27.7	37.1	40.0	40.9	41.7	41.7	41.7
Construction	33.0	24.6	0.0	0.0	0.0	0.0	0.0	0.0
Total Laboratory	646.5	620.1	686.8	724.5	748.3	751.7	751.7	751.7
Proposed construction	—	—	22.8	128.7	183.8	417.2	532.7	534.1
Total projected funding	—	—	709.6	853.2	932.1	1168.9	1284.4	1285.8

Table 8.2
Laboratory personnel summary by fiscal year
[Full-time equivalent (FTE) employees]

	1993	1994	1995	1996	1997	1998	1999	2000
Direct DOE effort	1532.7	1542.0	1556.7	1570.0	1601.5	1605.4	1605.4	1605.4
Work for others	299.5	304.1	292.2	278.5	278.5	278.5	278.5	278.5
Total technical direct personnel	1832.2	1846.1	1848.9	1848.5	1880.0	1883.9	1883.9	1883.9
Other direct	239.8	241.3	199.9	211.8	231.9	234.4	234.4	234.4
Total direct personnel	2072.0	2087.4	2048.8	2060.3	2111.9	2118.3	2118.3	2118.3
Indirect personnel	2650.0	2630.0	2350.0	2330.0	2287.0	2300.0	2300.0	2300.0
Total Laboratory	4722.0	4717.4	4398.8	4390.3	4398.9	4418.3	4418.3	4418.3

Table 8.3

Funding by assistant secretarial level office by fiscal year

($ in millions—BA)

	1993	1994	1995	1996	1997	1998	1999	2000
Office of Energy Research								
Operating expense	177.0	162.6	194.8	209.2	230.3	232.9	232.9	232.9
Capital equipment	11.7	11.2	15.9	17.9	18.8	19.6	19.6	19.6
Construction	1.8	1.5	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction	0.0	0.0	1.0	83.1	156.9	407.2	522.7	524.1
Total	190.5	175.3	211.7	310.2	406.0	659.7	775.2	776.6
Office of Science Education and Technical Information								
Operating expense	1.4	1.6	1.8	2.0	2.0	2.0	2.0	2.0
Office of Laboratory Management								
Operating expense	2.1	5.6	11.5	13.3	13.3	13.3	13.3	13.3
Capital equipment	0.2	5.9	7.0	10.0	10.0	10.0	10.0	10.0
Construction	0.7	7.6	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction	0.0	0.0	11.8	33.6	16.9	16.9	16.9	16.9
Total	3.0	19.1	30.3	56.9	40.2	40.2	40.2	40.2
Assistant Secretary for Energy Efficiency and Renewable Energy								
Operating expense	65.3	76.0	104.1	121.9	121.9	121.9	121.9	121.9
Capital equipment	2.9	3.2	2.5	3.5	3.5	3.5	3.5	3.5
Total	68.2	79.2	106.6	125.4	125.4	125.4	125.4	125.4
Assistant Secretary for Fossil Energy								
Operating expense	7.8	9.7	9.7	12.4	12.4	12.4	12.4	12.4
Capital equipment	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Total	7.8	9.7	9.8	12.5	12.5	12.5	12.5	12.5
Office of Nuclear Energy								
Operating expense	28.2	18.6	17.8	17.9	17.9	17.9	17.9	17.9
Capital equipment	0.1	(0.3)	1.5	0.9	0.9	0.9	0.9	0.9
Total	28.3	18.3	19.3	18.8	18.8	18.8	18.8	18.8
Energy Information Administration								
Operating expense	0.4	0.3	0.3	0.4	0.4	0.4	0.4	0.4
Office of Civilian Radioactive Waste Management								
Operating expense	1.7	0.1	0.5	0.5	0.5	0.5	0.5	0.5
Assistant Secretary for Defense Programs								
Operating expense	12.3	11.1	16.4	17.0	17.0	17.0	17.0	17.0
Capital equipment	3.1	0.6	0.6	1.3	1.3	1.3	1.3	1.3
Construction	4.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0
Total	20.0	11.7	17.0	20.3	18.3	18.3	18.3	18.3
Office of Nonproliferation and National Security								
Operating expense	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Capital equipment	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Assistant Secretary for Environmental Management								
Operating expense	20.9	4.7	4.5	4.5	4.5	4.5	4.5	4.5
Capital equipment	4.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	7.8	0.9	0.0	0.0	0.0	0.0	0.0	0.0
Total	33.0	5.6	4.5	4.5	4.5	4.5	4.5	4.5

Table 8.3
(continued)

	1993	1994	1995	1996	1997	1998	1999	2000
Assistant Secretary for Environment, Safety, and Health								
Operating expense	8.8	13.7	13.9	10.1	12.9	12.9	12.9	12.9
Capital equipment	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Total	8.8	13.7	14.0	10.2	13.0	13.0	13.0	13.0
Assistant Secretary for Policy, Planning and Program Evaluation								
Operating expense	2.5	1.0	2.4	2.7	2.7	2.7	2.7	2.7
Office of the Associate Deputy Secretary for Field Management								
Operating expense	0.4	0.4	0.9	0.3	0.3	0.3	0.3	0.3
Construction	0.4	2.1	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.8	2.5	0.9	0.3	0.3	0.3	0.3	0.3
Federal Energy Regulatory Commission								
Operating expense	1.0	0.5	1.3	1.3	1.3	1.3	1.3	1.3
Assistant Secretary for Human Resources and Administration								
Operating expense	0.2	0.0	0.3	0.3	0.3	0.3	0.3	0.3
Office of Economic Impact and Diversity								
Operating expense	0.0	0.4	1.0	1.5	1.5	1.5	1.5	1.5
DOE funding from Energy Systems central organizations								
Operating expense	151.9	171.4	170.9	171.0	170.0	170.0	170.0	170.0
Capital equipment	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Construction	17.7	12.5	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction	0.0	0.0	10.0	10.0	10.0	10.0	10.0	10.0
Total	172.1	128.9	183.4	183.5	182.5	182.5	182.5	182.5
Subtotal DOE Programs								
Operating expense	482.3	478.1	552.2	586.4	609.3	611.9	611.9	611.9
Capital equipment	24.9	23.1	30.2	36.3	37.2	38.0	38.0	38.0
Construction	33.0	24.6	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction	0.0	0.0	22.8	128.7	183.8	417.2	532.7	534.1
Total	540.2	525.8	605.2	751.4	830.3	1067.1	1182.6	1184.0
DOE Contractors and Operations Office								
Operating expense	25.0	15.9	19.7	19.3	19.3	19.3	19.3	19.3
Capital equipment	0.0	0.2	3.0	2.0	2.0	2.0	2.0	2.0
Total	25.0	16.1	22.7	21.3	21.3	21.3	21.3	21.3
Cooperative R&D Agreements								
Operating expense	1.2	0.6	0.3	0.1	0.1	0.1	0.1	0.1
Total DOE Programs								
Operating expense	508.5	494.6	572.2	605.8	628.7	631.3	631.3	631.3
Capital equipment	24.9	23.3	33.2	38.3	39.2	40.0	40.0	40.0
Construction	33.0	24.6	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction	0.0	0.0	22.8	128.7	183.8	417.2	532.7	534.1
Total	566.4	542.5	628.2	772.8	851.7	1088.5	1204.0	1205.4

Table 8.3
(continued)

	1993	1994	1995	1996	1997	1998	1999	2000
Work for others								
Nuclear Regulatory Commission								
Operating expense	18.4	19.3	20.6	20.3	20.3	20.3	20.3	20.3
Capital equipment	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total	18.5	19.4	20.6	20.3	20.3	20.3	20.3	20.3
Department of Defense								
Operating expense	34.0	23.5	26.0	28.0	28.0	28.0	28.0	28.0
Capital equipment	4.2	3.9	3.9	1.7	1.7	1.7	1.7	1.7
Total	38.2	27.4	29.9	29.7	29.7	29.7	29.7	29.7
National Aeronautics and Space Administration								
Operating expense	4.7	5.9	5.2	7.9	7.9	7.9	7.9	7.9
Department of Health and Human Services								
Operating expense	3.8	2.6	4.6	4.3	4.9	4.9	4.9	4.9
Environmental Protection Agency								
Operating expense	2.1	1.1	3.0	2.9	2.9	2.9	2.9	2.9
National Science Foundation								
Operating expense	0.8	0.1	0.5	0.5	0.5	0.5	0.5	0.5
Federal Emergency Management Agency								
Operating expense	1.7	2.0	2.9	2.2	2.2	2.2	2.2	2.2
Department of Transportation								
Operating expense	5.7	9.0	8.9	6.7	6.7	6.7	6.7	6.7
Capital equipment	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Total	5.8	9.2	8.9	6.7	6.7	6.7	6.7	6.7
Other Federal agencies								
Operating expense	0.7	3.3	2.4	2.4	2.4	2.4	2.4	2.4
Capital equipment	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.8	3.5	2.4	2.4	2.4	2.4	2.4	2.4
Electric Power Research Institute								
Operating expense	1.7	1.8	1.7	1.8	1.8	1.8	1.8	1.8
Other nonfederal agencies								
Operating expense	2.0	5.2	1.7	1.7	1.7	1.7	1.7	1.7
Total Work for Others								
Operating expense	75.6	73.8	77.5	78.7	78.7	78.7	78.7	78.7
Capital equipment	4.5	4.4	3.9	1.7	1.7	1.7	1.7	1.7
Total	80.1	78.2	81.4	80.4	80.4	80.4	80.4	80.4
Total Laboratory								
Operating expense	584.1	568.4	649.7	684.5	707.4	710.0	710.0	710.0
Capital equipment	29.4	27.7	37.1	40.0	40.9	41.7	41.7	41.7
Construction	33.0	24.6	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction	0.0	0.0	22.8	128.7	183.8	417.2	532.7	534.1
Total	646.5	620.7	709.6	853.2	932.1	1168.9	1284.4	1285.8

Table 8.4

Personnel by assistant secretarial level office by fiscal year

[Full-time equivalent (FTE) employees]

	1993	1994	1995	1996	1997	1998	1999	2000
Office of Energy Research								
Technical personnel	603.7	576.5	565.4	571.3	602.8	606.7	606.7	606.7
Other direct personnel	94.9	79.1	49.0	65.7	85.8	88.3	88.3	88.3
Total direct personnel	698.6	655.6	614.4	637.0	688.6	695.0	695.0	695.0
Office of Science Education and Technical Information								
Technical personnel	3.6	3.3	2.4	2.3	2.3	2.3	2.3	2.3
Other direct personnel	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	3.9	3.5	2.4	2.3	2.3	2.3	2.3	2.3
Office of Laboratory Management								
Technical personnel	4.5	12.9	13.5	18.7	18.7	18.7	18.7	18.7
Other direct personnel	0.3	0.5	1.0	1.1	1.1	1.1	1.1	1.1
Total direct personnel	4.8	13.4	14.5	19.8	19.8	19.8	19.8	19.8
Assistant Secretary for Energy Efficiency and Renewable Energy								
Technical personnel	170.2	178.3	194.7	197.9	197.9	197.9	197.9	197.9
Other direct personnel	7.5	9.1	4.1	5.3	5.3	5.3	5.3	5.3
Total direct personnel	177.8	187.4	198.8	203.2	203.2	203.2	203.2	203.2
Assistant Secretary for Fossil Energy								
Technical personnel	20.0	22.9	25.1	28.0	28.0	28.0	28.0	28.0
Other direct personnel	0.9	0.8	0.5	0.6	0.6	0.6	0.6	0.6
Total direct personnel	20.9	23.7	25.6	28.6	28.6	28.6	28.6	28.6
Office of Nuclear Energy								
Technical personnel	104.6	66.7	69.3	68.3	68.3	68.3	68.3	68.3
Other direct personnel	5.6	0.7	0.9	0.9	0.9	0.9	0.9	0.9
Total direct personnel	110.2	67.4	70.2	69.2	69.2	69.2	69.2	69.2
Energy Information Administration								
Technical personnel	1.4	0.9	1.0	1.0	1.0	1.0	1.0	1.0
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	1.4	0.9	1.0	1.0	1.0	1.0	1.0	1.0
Office of Civilian Radioactive Waste Management								
Technical personnel	4.7	5.4	2.9	2.5	2.5	2.5	2.5	2.5
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	4.7	5.4	2.9	2.5	2.5	2.5	2.5	2.5
Assistant Secretary for Defense Programs								
Technical personnel	45.7	42.8	51.7	52.9	52.9	52.9	52.9	52.9
Other direct personnel	2.1	2.3	2.1	1.9	1.9	1.9	1.9	1.9
Total direct personnel	47.8	45.1	53.8	54.8	54.8	54.8	54.8	54.8
Office of Nonproliferation and National Security								
Technical personnel	1.2	0.4	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	0.0
Total direct personnel	1.2	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Assistant Secretary for Environmental Management								
Technical personnel	53.6	24.0	23.0	23.0	23.0	23.0	23.0	23.0
Other direct personnel	2.1	2.2	2.0	2.0	2.0	2.0	2.0	2.0
Total direct personnel	55.7	26.2	25.0	25.0	25.0	25.0	25.0	25.0

Table 8.4
(continued)

	1993	1994	1995	1996	1997	1998	1999	2000
Assistant Secretary for Environment, Safety, and Health								
Technical personnel	26.6	42.9	34.2	29.1	29.1	29.1	29.1	29.1
Other direct personnel	1.4	3.6	3.5	3.5	3.5	3.5	3.5	3.5
Total direct personnel	28.1	46.5	37.7	32.6	32.6	32.6	32.6	32.6
Assistant Secretary for Policy, Planning and Program Evaluation								
Technical personnel	9.1	7.1	7.5	7.7	7.7	7.7	7.7	7.7
Other direct personnel	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	9.2	7.1	7.5	7.7	7.7	7.7	7.7	7.7
Federal Energy Regulatory Commission								
Technical personnel	2.4	5.2	11.6	7.9	7.9	7.9	7.9	7.9
Other direct personnel	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	2.4	6.0	11.6	7.9	7.9	7.9	7.9	7.9
Assistant Secretary for Human Resources and Administration								
Technical personnel	0.3	0.9	1.0	1.0	1.0	1.0	1.0	1.0
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	0.3	0.9	1.0	1.0	1.0	1.0	1.0	1.0
Office of Economic Impact and Diversity								
Technical personnel	0.0	0.2	0.4	0.5	0.5	0.5	0.5	0.5
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	0.0	0.2	0.6	0.5	0.5	0.5	0.5	0.5
DOE funding from Energy Systems central organizations								
Technical personnel	387.2	484.5	487.0	487.0	487.0	487.0	487.0	487.0
Other direct personnel	90.7	102.3	105.4	105.5	105.5	105.5	105.5	105.5
Total direct personnel	477.9	586.8	592.4	592.5	592.5	592.5	592.5	592.5
Subtotal DOE Programs								
Technical personnel	1439.0	1474.9	1485.7	1497.1	1528.6	1532.5	2246.0	2246.0
Other direct personnel	206.8	203.7	170.5	187.7	207.8	210.3	307.1	307.1
Total direct personnel	1645.8	1678.6	1656.2	1684.8	1736.4	1742.8	1742.8	1742.8
DOE Contractors and Operations Office								
Technical personnel	89.4	63.5	69.2	72.6	72.6	72.6	72.6	72.6
Other direct personnel	11.8	11.0	9.4	9.3	9.3	9.3	9.3	9.3
Total direct personnel	101.2	74.5	78.6	81.9	81.9	81.9	81.9	81.9
Cooperative R&D Agreements								
Technical personnel	4.3	3.6	1.8	0.3	0.3	0.3	0.3	0.3
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	4.3	3.6	1.8	0.3	0.3	0.3	0.3	0.3
Total DOE Programs								
Technical personnel	1532.7	1542.0	1556.7	1570.0	1601.5	1605.4	1605.4	1605.4
Other direct personnel	218.6	214.7	179.9	197.0	217.1	219.6	321.2	321.2
Total direct personnel	1751.3	1756.7	1736.6	1767.0	1818.6	1825.0	1825.0	1825.0
Work for others								
Nuclear Regulatory Commission								
Technical personnel	72.1	80.9	75.2	73.6	73.6	73.6	73.6	73.6
Other direct personnel	3.9	4.5	3.8	5.9	5.9	5.9	5.9	5.9
Total direct personnel	76.0	85.4	79.0	79.5	79.5	79.5	79.5	79.5

Table 8.4
(continued)

	1993	1994	1995	1996	1997	1998	1999	2000
Department of Defense								
Technical personnel	128.0	121.5	120.8	118.6	118.6	118.6	118.6	118.6
Other direct personnel	14.9	20.1	11.6	6.0	6.0	6.0	6.0	6.0
Total direct personnel	142.9	141.6	132.4	124.6	124.6	124.6	124.6	124.6
National Aeronautics and Space Administration								
Technical personnel	7.1	12.9	12.0	12.8	12.8	12.8	12.8	12.8
Other direct personnel	0.1	0.3	3.9	2.6	2.6	2.6	2.6	2.6
Total direct personnel	7.2	13.2	15.9	15.4	15.4	15.4	15.4	15.4
Department of Health and Human Services								
Technical personnel	17.1	15.8	14.9	15.3	15.3	15.3	15.3	15.3
Other direct personnel	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	17.2	15.9	14.9	15.3	15.3	15.3	15.3	15.3
Environmental Protection Agency								
Technical personnel	10.2	10.4	12.2	10.2	10.2	10.2	10.2	10.2
Other direct personnel	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	10.3	10.5	12.2	10.2	10.2	10.2	10.2	10.2
National Science Foundation								
Technical personnel	4.2	3.2	2.1	1.8	1.8	1.8	1.8	1.8
Other direct personnel	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	4.3	3.4	2.1	1.8	1.8	1.8	1.8	1.8
Federal Emergency Management Agency								
Technical personnel	5.8	4.6	7.3	5.9	5.9	5.9	5.9	5.9
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	5.8	4.6	7.3	5.9	5.9	5.9	5.9	5.9
Department of Transportation								
Technical personnel	12.9	17.4	20.2	19.5	19.5	19.5	19.5	19.5
Other direct personnel	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total direct personnel	12.9	17.5	20.3	19.6	19.6	19.6	19.6	19.6
Other Federal agencies								
Technical personnel	14.3	10.9	8.9	5.6	5.6	5.6	5.6	5.6
Other direct personnel	1.6	0.3	0.3	0.0	0.0	0.0	0.0	0.0
Total direct personnel	15.9	11.2	9.2	5.6	5.6	5.6	5.6	5.6
Electric Power Research Institute								
Technical personnel	8.0	7.6	7.0	7.8	7.8	7.8	7.8	7.8
Other direct personnel	0.3	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Total direct personnel	8.3	7.7	7.2	8.0	8.0	8.0	8.0	8.0
Other nonfederal agencies								
Technical personnel	19.8	18.9	11.6	7.4	7.4	7.4	7.4	7.4
Other direct personnel	0.1	0.8	0.1	0.0	0.0	0.0	0.0	0.0
Total direct personnel	19.9	19.7	11.7	7.4	7.4	7.4	7.4	7.4
Total Work for Others								
Technical personnel	299.5	304.1	292.2	278.5	278.5	278.5	278.5	278.5
Other direct personnel	21.2	26.6	20.0	14.8	14.8	14.8	14.8	14.8
Total direct personnel	320.7	330.7	312.2	293.3	293.3	293.3	293.3	293.3

Table 8.4
(continued)

	1993	1994	1995	1996	1997	1998	1999	2000
Total Laboratory								
Technical personnel	1832.2	1846.1	1848.9	1848.5	1880.0	1883.9	1883.9	1883.9
Other direct personnel	239.8	241.3	199.9	211.8	231.9	234.4	351.0	351.0
Total Laboratory direct personnel	2072.0	2087.4	2048.8	2060.3	2111.9	2118.3	2234.9	2234.9
Total Laboratory indirect personnel	2650.0	2630.0	2350.0	2330.0	2287.0	2300.0	2300.0	2300.0
Total Laboratory personnel	4722.0	4717.4	4398.8	4390.3	4398.9	4418.3	4534.9	4534.9

Table 8.5
Resources by program by fiscal year
($ in millions)

	1993	1994	1995	1996	1997	1998	1999	2000
Office of Energy Research								
Magnetic Fusion—AT								
Total operating	30.1	29.8	33.2	34.2	34.2	34.2	34.2	34.2
Capital equipment	2.7	1.6	1.0	1.2	1.2	1.2	1.2	1.2
Total program	32.8	31.4	34.2	35.4	35.4	35.4	35.4	35.4
Technical personnel	87.3	91.7	85.2	78.9	78.9	78.9	78.9	78.9
Other direct personnel	30.0	26.0	27.8	31.2	31.2	31.2	31.2	31.2
Total direct personnel	117.3	117.7	113.0	110.1	110.1	110.1	110.1	110.1
High Energy Physics—KA								
Total operating	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.5
Technical personnel	2.4	1.7	1.7	1.7	1.7	1.7	1.7	1.7
Other direct personnel	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	2.5	1.7	1.7	1.7	1.7	1.7	1.7	1.7
Nuclear Physics—KB								
Total operating	10.5	9.6	11.4	12.8	12.8	12.8	12.8	12.8
Capital equipment	0.9	2.3	1.8	2.1	2.1	2.1	2.1	2.1
Construction	0.8	1.0	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction	0.0	0.0	1.0	0.8	0.0	0.0	0.0	0.0
Total program	12.2	12.9	14.2	15.7	14.9	14.9	14.9	14.9
Technical personnel	52.8	41.8	43.2	47.3	47.3	47.3	47.3	47.3
Other direct personnel	1.3	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Total direct personnel	54.1	41.9	43.4	47.5	47.5	47.5	47.5	47.5
Basic Energy Sciences—KC								
Total operating	104.5	80.6	96.5	102.0	102.0	102.0	102.0	102.0
Capital equipment	7.3	6.3	8.7	7.9	7.9	7.9	7.9	7.9
Construction	1.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0
Total program	112.8	87.4	105.2	109.9	109.9	109.9	109.9	109.9
Technical personnel	358.2	302.5	308.7	312.2	312.2	312.2	312.2	312.2
Other direct personnel	60.0	11.0	8.6	8.7	8.7	8.7	8.7	8.7
Total direct personnel	418.2	313.5	317.3	320.9	320.9	320.9	320.9	320.9
Energy Research Analyses—KD								
Total operating	2.4	0.7	2.1	2.4	2.4	2.4	2.4	2.4
Technical personnel	4.3	2.8	3.3	3.3	3.3	3.3	3.3	3.3
Other direct personnel	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	4.4	2.8	3.3	3.3	3.3	3.3	3.3	3.3
Advanced Neutron Source—KE								
Total operating	0.0	15.5	18.2	23.5	44.6	47.2	47.2	47.2
Capital equipment	0.0	0.0	1.0	2.9	3.8	4.6	4.6	4.6
Proposed construction	0.0	0.0	0.0	64.3	113.9	365.3	522.7	524.1
Total program	0.0	15.5	19.2	90.7	162.3	417.1	574.5	575.9
Technical personnel	0.0	41.7	31.1	35.1	66.6	70.5	70.5	70.5
Other direct personnel	0.0	38.0	9.1	22.5	42.6	45.1	45.1	45.1
Total direct personnel	0.0	79.7	40.2	57.6	109.2	115.6	115.6	115.6

Table 8.5
(continued)

	1993	1994	1995	1996	1997	1998	1999	2000
Biological and Environmental Research—KP								
Total operating	29.1	25.9	32.9	33.8	33.8	33.8	33.8	33.8
Capital equipment	0.8	1.0	3.4	3.8	3.8	3.8	3.8	3.8
Proposed construction	0.0	0.0	0.0	18.0	43.0	41.9	0.0	0.0
Total program	29.9	26.9	36.3	55.6	80.6	79.5	37.6	37.6
Technical personnel	98.2	92.9	92.2	92.8	92.8	92.8	92.8	92.8
Other direct personnel	3.4	4.0	3.3	3.1	3.1	3.1	3.1	3.1
Total direct personnel	101.6	96.9	95.5	95.9	95.9	95.9	95.9	95.9
Superconducting Super Collider—KS								
Total operating	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Technical personnel	0.5	1.4	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	0.0
Total direct personnel	0.5	1.4	0.0	0.0	0.0	0.0	0.0	0.0
Total Office of Energy Research								
Operating expense	177.0	162.6	194.8	209.2	230.3	232.9	232.9	232.9
Capital equipment	11.7	11.2	15.9	17.9	18.8	19.6	19.6	19.6
Construction	1.8	1.5	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction	0.0	0.0	1.0	83.1	156.9	407.2	522.7	524.1
Total program	190.5	175.3	211.7	310.2	406.0	659.7	775.2	776.6
Technical personnel	603.7	576.5	565.4	571.3	602.8	606.7	606.7	606.7
Other direct personnel	94.9	79.1	49.0	65.7	85.8	88.3	88.3	88.3
Total direct personnel	698.6	655.6	614.4	637.0	688.6	695.0	695.0	695.0
Office of Science Education and Technical Information								
University & Science Education—KT								
Total operating	0.1	1.6	1.8	2.0	2.0	2.0	2.0	2.0
Technical personnel	0.9	2.3	2.4	2.3	2.3	2.3	2.3	2.3
Other direct personnel	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	1.0	2.4	2.4	2.3	2.3	2.3	2.3	2.3
University & Science Education—KV								
Total operating	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Technical personnel	2.7	1.0	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	2.9	1.1	0.0	0.0	0.0	0.0	0.0	0.0
Total Office of Science Education and Technical Information								
Total operating	1.4	1.6	1.8	2.0	2.0	2.0	2.0	2.0
Technical personnel	3.6	3.3	2.4	2.3	2.3	2.3	2.3	2.3
Other direct personnel	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	3.9	3.5	2.4	2.3	2.3	2.3	2.3	2.3
Office of Laboratory Management								
Multiprogram Energy Laboratory—Facility Support—KG								
Total operating	0.0	0.6	0.7	1.0	1.0	1.0	1.0	1.0
Capital equipment	0.2	5.9	7.0	10.0	10.0	10.0	10.0	10.0
Construction (MGPF)	0.7	7.6	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction	0.0	0.0	11.8	33.6	16.9	0.0	0.0	0.0
Total program	0.9	14.1	19.5	44.6	27.9	11.0	11.0	11.0
Technical personnel	0.0	2.2	3.0	4.0	4.0	4.0	4.0	4.0
Other direct personnel	0.0	0.3	0.5	0.5	0.5	0.5	0.5	0.5
Total direct personnel	0.0	2.5	3.5	4.5	4.5	4.5	4.5	4.5

Table 8.5
(continued)

	1993	1994	1995	1996	1997	1998	1999	2000
Technology Transfer—KU								
Total operating	2.1	5.0	10.8	12.3	12.3	12.3	12.3	12.3
Technical personnel	4.5	10.7	10.5	14.7	14.7	14.7	14.7	14.7
Other direct personnel	0.3	0.2	0.5	0.6	0.6	0.6	0.6	0.6
Total direct personnel	4.8	10.9	11.0	15.3	15.3	15.3	15.3	15.3
Total Office of Laboratory Management								
Total operating	2.1	5.6	11.5	13.3	13.3	13.3	13.3	13.3
Capital equipment	0.2	5.9	7.0	10.0	10.0	10.0	10.0	10.0
Construction (MGPF)	0.7	7.6	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction	0.0	0.0	11.8	33.6	16.9	0.0	0.0	0.0
Total program	3.0	19.1	30.3	56.9	40.2	23.3	23.3	23.3
Technical personnel	4.5	12.9	13.5	18.7	18.7	18.7	18.7	18.7
Other direct personnel	0.3	0.5	1.0	1.1	1.1	1.1	1.1	1.1
Total direct personnel	4.8	13.4	14.5	19.8	19.8	19.8	19.8	19.8
Assistant Secretary for Energy Efficiency and Renewable Energy								
Electric Energy Systems—AK								
Total operating	10.2	13.1	17.9	19.9	19.9	19.9	19.9	19.9
Capital equipment	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Total program	10.4	13.4	18.2	20.2	20.2	20.2	20.2	20.2
Technical personnel	22.6	28.4	28.3	28.2	28.2	28.2	28.2	28.2
Other direct personnel	0.6	0.7	1.5	1.7	1.7	1.7	1.7	1.7
Total direct personnel	23.2	29.1	29.8	29.9	29.9	29.9	29.9	29.9
Energy Storage Systems—AL								
Total operating	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Technical personnel	1.0	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	0.0
Total direct personnel	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Geothermal Energy —AM								
Total operating	(0.9)	0.0	1.1	1.0	1.0	1.0	1.0	1.0
Technical personnel	5.0	3.4	4.3	2.9	2.9	2.9	2.9	2.9
Other direct personnel	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	5.1	3.5	4.3	2.9	2.9	2.9	2.9	2.9
Hydrogen Research—AR								
Total operating	0.0	0.4	0.5	0.5	0.5	0.5	0.5	0.5
Technical personnel	0.0	0.8	2.2	2.1	2.1	2.1	2.1	2.1
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	0.0	0.8	2.2	2.1	2.1	2.1	2.1	2.1
Hydropower—CE								
Total operating	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Technical personnel	1.3	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Other direct personnel	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Total direct personnel	1.3	0.7	0.8	0.8	0.8	0.8	0.8	0.8

Table 8.5
(continued)

	1993	1994	1995	1996	1997	1998	1999	2000
Solar Energy—EB								
Total operating	4.5	4.7	7.4	7.5	7.5	7.5	7.5	7.5
Capital equipment	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Total program	4.6	4.8	7.6	7.7	7.7	7.7	7.7	7.7
Technical personnel	9.7	11.6	12.3	12.1	12.1	12.1	12.1	12.1
Other direct personnel	0.6	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Total direct personnel	10.3	12.5	13.2	13.0	13.0	13.0	13.0	13.0
Buildings Sector—EC								
Total operating	10.9	13.6	13.3	14.2	14.2	14.2	14.2	14.2
Capital equipment	0.5	0.4	0.6	0.7	0.7	0.7	0.7	0.7
Total program	11.4	14.0	13.9	14.9	14.9	14.9	14.9	14.9
Technical personnel	36.1	37.6	41.7	40.6	40.6	40.6	40.6	40.6
Other direct personnel	2.6	3.3	0.3	0.4	0.4	0.4	0.4	0.4
Total direct personnel	38.7	40.9	42.0	41.0	41.0	41.0	41.0	41.0
Industrial Sector—ED								
Total operating	10.7	11.1	20.0	22.1	22.1	22.1	22.1	22.1
Capital equipment	0.3	0.5	0.6	0.7	0.7	0.7	0.7	0.7
Total program	11.0	11.6	20.6	22.8	22.8	22.8	22.8	22.8
Technical personnel	31.3	30.6	30.3	30.3	30.3	30.3	30.3	30.3
Other direct personnel	1.2	0.9	0.2	0.2	0.2	0.2	0.2	0.2
Total direct personnel	32.4	31.5	30.5	30.5	30.5	30.5	30.5	30.5
Transportation Sector—EE								
Total operating	27.0	30.1	41.3	53.5	53.5	53.5	53.5	53.5
Capital equipment	1.8	1.9	0.8	1.6	1.6	1.6	1.6	1.6
Total program	28.8	32.0	42.1	55.1	55.1	55.1	55.1	55.1
Technical personnel	53.6	55.4	66.0	72.3	72.3	72.3	72.3	72.3
Other direct personnel	1.9	2.4	1.1	2.0	2.0	2.0	2.0	2.0
Total direct personnel	55.5	57.8	67.1	74.3	74.3	74.3	74.3	74.3
Technical and Financial Assistance—EF								
Total operating	1.7	1.6	1.4	1.5	1.5	1.5	1.5	1.5
Technical personnel	5.6	4.6	3.4	3.3	3.3	3.3	3.3	3.3
Other direct personnel	0.6	0.7	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	6.2	5.3	3.4	3.3	3.3	3.3	3.3	3.3
Utility Sector—EK								
Total operating	0.9	1.1	0.9	1.4	1.4	1.4	1.4	1.4
Technical personnel	4.0	5.2	5.5	5.4	5.4	5.4	5.4	5.4
Other direct personnel	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	4.0	5.3	5.5	5.4	5.4	5.4	5.4	5.4
Total Assistant Secretary for Energy Efficiency and Renewable Energy								
Operating expense	65.3	76.0	104.1	121.9	121.9	121.9	121.9	121.9
Capital equipment	2.9	3.2	2.5	3.5	3.5	3.5	3.5	3.5
Total	68.2	79.2	106.6	125.4	125.4	125.4	125.4	125.4
Technical personnel	170.2	178.3	194.7	197.9	197.9	197.9	197.9	197.9
Other direct personnel	7.5	9.1	4.1	5.3	5.3	5.3	5.3	5.3
Total direct personnel	177.8	187.4	198.8	203.2	203.2	203.2	203.2	203.2

Table 8.5
(continued)

	1993	1994	1995	1996	1997	1998	1999	2000
Assistant Secretary for Fossil Energy								
Coal—AA								
Total operating	6.3	7.9	6.3	8.1	8.1	8.1	8.1	8.1
Capital equipment	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Total program	6.3	7.9	6.4	8.2	8.2	8.2	8.2	8.2
Technical personnel	16.1	18.0	16.5	19.5	19.5	19.5	19.5	19.5
Other direct personnel	0.2	0.1	0.0	0.1	0.1	0.1	0.1	0.1
Total direct personnel	16.3	18.1	16.5	19.6	19.6	19.6	19.6	19.6
Gas—AB								
Total operating	0.0	0.6	1.5	2.0	2.0	2.0	2.0	2.0
Technical personnel	0.0	0.2	0.5	0.5	0.5	0.5	0.5	0.5
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	0.0	0.2	0.5	0.5	0.5	0.5	0.5	0.5
Petroleum—AC								
Total operating	0.7	0.0	0.8	0.8	0.8	0.8	0.8	0.8
Technical personnel	0.0	0.8	1.5	1.6	1.6	1.6	1.6	1.6
Other direct personnel	0.0	0.0	0.5	0.5	0.5	0.5	0.5	0.5
Total direct personnel	0.0	0.8	2.0	2.1	2.1	2.1	2.1	2.1
Fossil Energy Environmental Restoration—AW								
Total operating	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Technical personnel	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Innovative Clean Coal Technology—AZ								
Total operating	0.4	1.1	0.6	1.0	1.0	1.0	1.0	1.0
Technical personnel	2.7	2.7	4.6	4.4	4.4	4.4	4.4	4.4
Other direct personnel	0.7	0.7	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	3.4	3.4	4.6	4.4	4.4	4.4	4.4	4.4
Strategic Petroleum Reserve—SA								
Total operating	0.3	0.0	0.5	0.5	0.5	0.5	0.5	0.5
Technical personnel	1.0	1.1	2.0	2.0	2.0	2.0	2.0	2.0
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	1.0	1.1	2.0	2.0	2.0	2.0	2.0	2.0
Total Assistant Secretary for Fossil Energy								
Operating expense	7.8	9.7	9.7	12.4	12.4	12.4	12.4	12.4
Capital equipment	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Total program	7.8	9.7	9.8	12.5	12.5	12.5	12.5	12.5
Technical personnel	20.0	22.9	25.1	28.0	28.0	28.0	28.0	28.0
Other direct personnel	0.9	0.8	0.5	0.6	0.6	0.6	0.6	0.6
Total direct personnel	20.9	23.7	25.6	28.6	28.6	28.6	28.6	28.6

Table 8.5
(continued)

	1993	1994	1995	1996	1997	1998	1999	2000
Office of Nuclear Energy								
Nuclear Energy R&D—AF								
Total operating	17.8	10.8	9.8	9.5	9.5	9.5	9.5	9.5
Capital equipment	0.1	(0.3)	1.5	0.9	0.9	0.9	0.9	0.9
Total program	17.9	10.5	11.3	10.4	10.4	10.4	10.4	10.4
Technical personnel	79.4	53.8	53.9	53.0	53.0	53.0	53.0	53.0
Other direct personnel	2.5	0.7	0.4	0.4	0.4	0.4	0.4	0.4
Total direct personnel	81.9	54.5	54.3	53.4	53.4	53.4	53.4	53.4
Naval Reactors—AJ								
Total operating	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Technical personnel	0.3	0.5	0.4	0.4	0.4	0.4	0.4	0.4
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	0.3	0.5	0.4	0.4	0.4	0.4	0.4	0.4
Uranium Enrichment—CD								
Total operating	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Technical personnel	2.7	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	2.8	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Policy and Management—Nuclear Energy—KK								
Total operating	2.9	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Technical personnel	12.3	2.7	2.8	2.7	2.7	2.7	2.7	2.7
Other direct personnel	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	15.0	2.7	2.8	2.7	2.7	2.7	2.7	2.7
Isotope Production and Distribution Program—ST								
Total operating	6.7	7.1	7.3	7.7	7.7	7.7	7.7	7.7
Technical personnel	9.9	9.3	12.2	12.2	12.2	12.2	12.2	12.2
Other direct personnel	0.3	0.0	0.5	0.5	0.5	0.5	0.5	0.5
Total direct personnel	10.2	9.3	12.7	12.7	12.7	12.7	12.7	12.7
Total Office of Nuclear Energy								
Operating expense	28.2	18.6	17.8	17.9	17.9	17.9	17.9	17.9
Capital equipment	0.1	(0.3)	1.5	0.9	0.9	0.9	0.9	0.9
Total	28.3	18.3	19.3	18.8	18.8	18.8	18.8	18.8
Technical personnel	104.6	66.7	69.3	68.3	68.3	68.3	68.3	68.3
Other direct personnel	5.6	0.7	0.9	0.9	0.9	0.9	0.9	0.9
Total direct personnel	110.2	67.4	70.2	69.2	69.2	69.2	69.2	69.2
Energy Information Administration								
National Energy Information System—TA								
Operating expense	0.4	0.3	0.3	0.4	0.4	0.4	0.4	0.4
Technical personnel	1.4	0.9	1.0	1.0	1.0	1.0	1.0	1.0
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	1.4	0.9	1.0	1.0	1.0	1.0	1.0	1.0
Total Energy Information Administration								
Operating expense	0.4	0.3	0.3	0.4	0.4	0.4	0.4	0.4
Technical personnel	1.4	0.9	1.0	1.0	1.0	1.0	1.0	1.0
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	1.4	0.9	1.0	1.0	1.0	1.0	1.0	1.0

Table 8.5
(continued)

	1993	1994	1995	1996	1997	1998	1999	2000
Office of Civilian Radioactive Waste Management								
Nuclear Waste Fund—DB								
Total operating	1.7	0.1	0.5	0.5	0.5	0.5	0.5	0.5
Technical personnel	4.7	5.4	2.9	2.5	2.5	2.5	2.5	2.5
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	4.7	5.4	2.9	2.5	2.5	2.5	2.5	2.5
Total Office of Civilian Radioactive Waste Management								
Total operating	1.7	0.1	0.5	0.5	0.5	0.5	0.5	0.5
Technical personnel	4.7	5.4	2.9	2.5	2.5	2.5	2.5	2.5
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	4.7	5.4	2.9	2.5	2.5	2.5	2.5	2.5
Assistant Secretary for Defense Programs								
Fissile Materials Disposition—GA								
Total operating	0.0	0.0	3.5	3.5	3.5	3.5	3.5	3.5
Technical personnel	0.0	0.0	10.0	10.0	10.0	10.0	10.0	10.0
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	0.0	0.0	10.0	10.0	10.0	10.0	10.0	10.0
Weapons Activities—GB								
Total operating	0.3	0.9	0.3	0.4	0.4	0.4	0.4	0.4
Technical personnel	1.6	4.1	1.5	1.5	1.5	1.5	1.5	1.5
Other direct personnel	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	1.6	4.3	1.5	1.5	1.5	1.5	1.5	1.5
Materials Production—GE								
Total operating	12.3	9.5	12.6	13.1	13.1	13.1	13.1	13.1
Capital equipment	3.1	0.5	0.6	1.3	1.3	1.3	1.3	1.3
Construction	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0
Total program	16.5	10.0	13.2	16.4	14.4	14.4	14.4	14.4
Technical personnel	44.0	38.2	40.2	41.4	41.4	41.4	41.4	41.4
Other direct personnel	2.1	2.1	2.1	1.9	1.9	1.9	1.9	1.9
Total direct personnel	46.1	40.3	42.3	43.3	43.3	43.3	43.3	43.3
New Production Reactors—NP								
Total operating	(0.3)	0.7	0.0	0.0	0.0	0.0	0.0	0.0
Capital equipment	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Construction	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total program	3.2	0.8	0.0	0.0	0.0	0.0	0.0	0.0
Technical personnel	0.1	0.5	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	0.0
Total direct personnel	0.1	0.5	0.0	0.0	0.0	0.0	0.0	0.0
Total Assistant Secretary for Defense Programs								
Total operating	12.3	11.1	16.4	17.0	17.0	17.0	17.0	17.0
Capital equipment	3.1	0.6	0.6	1.3	1.3	1.3	1.3	1.3
Construction	4.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0
Total program	20.0	11.7	17.0	20.3	18.3	18.3	18.3	18.3
Technical personnel	45.7	42.8	51.7	52.9	52.9	52.9	52.9	52.9
Other direct personnel	2.1	2.3	2.1	1.9	1.9	1.9	1.9	1.9
Total direct personnel	47.8	45.1	53.8	54.8	54.8	54.8	54.8	54.8

Table 8.5
(continued)

	1993	1994	1995	1996	1997	1998	1999	2000
Office of Nonproliferation and National Security								
Nuclear Safeguards and Security—GD								
Total operating	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital equipment	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total program	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Technical personnel	1.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	1.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Emergency Preparedness—NB								
Total operating	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Technical personnel	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total Office of Nonproliferation and National Security								
Total operating	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Capital equipment	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total program	0.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Technical personnel	1.2	0.4	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	0.0
Total direct personnel	1.2	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Assistant Secretary for Environmental Management								
Environmental Restoration and Waste Management—Defense—EW								
Total operating	7.1	1.2	1.0	1.0	1.0	1.0	1.0	1.0
Construction	0.2	(2.3)	0.0	0.0	0.0	0.0	0.0	0.0
Total program	7.3	(1.1)	1.0	1.0	1.0	1.0	1.0	1.0
Technical personnel	24.2	9.4	8.0	8.0	8.0	8.0	8.0	8.0
Other direct personnel	0.6	0.7	0.5	0.5	0.5	0.5	0.5	0.5
Total direct personnel	24.8	10.1	8.5	8.5	8.5	8.5	8.5	8.5
Environmental Restoration and Waste Management—Non-Defense—EX								
Total operating	13.8	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Capital equipment (Landlord)	4.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction (GPP)	7.6	3.2	0.0	0.0	0.0	0.0	0.0	0.0
Total program	25.7	6.7	3.5	3.5	3.5	3.5	3.5	3.5
Technical personnel	29.4	14.6	15.0	15.0	15.0	15.0	15.0	15.0
Other direct personnel	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Total direct personnel	30.9	16.1	16.5	16.5	16.5	16.5	16.5	16.5
Total Assistant Secretary for Environmental Management								
Total operating	20.9	4.7	4.5	4.5	4.5	4.5	4.5	4.5
Capital equipment	4.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	7.8	0.9	0.0	0.0	0.0	0.0	0.0	0.0
Total program	33.0	5.6	4.5	4.5	4.5	4.5	4.5	4.5
Technical personnel	53.6	24.0	23.0	23.0	23.0	23.0	23.0	23.0
Other direct personnel	2.1	2.2	2.0	2.0	2.0	2.0	2.0	2.0
Total direct personnel	55.7	26.2	25.0	25.0	25.0	25.0	25.0	25.0

Table 8.5
(continued)

	1993	1994	1995	1996	1997	1998	1999	2000
Assistant Secretary for Environment, Safety, and Health								
Environmental Research and Development—HA								
Total operating	7.2	10.7	9.9	6.0	8.8	8.8	8.8	8.8
Capital equipment	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Total program	7.2	10.7	10.0	6.1	8.9	8.9	8.9	8.9
Technical personnel	22.6	33.0	24.7	19.3	19.3	19.3	19.3	19.3
Other direct personnel	1.0	1.5	1.0	1.0	1.0	1.0	1.0	1.0
Total direct personnel	23.6	34.5	25.7	20.3	20.3	20.3	20.3	20.3
Nuclear Safety Policy—HP								
Total operating	0.0	3.2	3.7	3.8	3.8	3.8	3.8	3.8
Technical personnel	0.0	8.1	9.1	9.3	9.3	9.3	9.3	9.3
Other direct personnel	0.0	1.9	2.5	2.5	2.5	2.5	2.5	2.5
Total direct personnel	0.0	10.0	11.6	11.8	11.8	11.8	11.8	11.8
Epidemiological Activities—HR								
Total operating	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3
Technical personnel	0.0	0.2	0.4	0.5	0.5	0.5	0.5	0.5
Other direct personnel	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	0.0	0.3	0.4	0.5	0.5	0.5	0.5	0.5
Office of Security Evaluations—HS								
Total operating	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Technical personnel	0.2	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	0.0
Total direct personnel	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Office of Nuclear Safety—NS								
Total operating	1.5	(0.2)	0.0	0.0	0.0	0.0	0.0	0.0
Technical personnel	3.8	1.6	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	4.2	1.7	0.0	0.0	0.0	0.0	0.0	0.0
Total Assistant Secretary for Environment, Safety, and Health								
Total operating	8.8	13.7	13.9	10.1	12.9	12.9	12.9	12.9
Capital equipment	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Total program	8.8	13.7	14.0	10.2	13.0	13.0	13.0	13.0
Technical personnel	26.6	42.9	34.2	29.1	29.1	29.1	29.1	29.1
Other direct personnel	1.4	3.6	3.5	3.5	3.5	3.5	3.5	3.5
Total direct personnel	28.0	46.5	37.7	32.6	32.6	32.6	32.6	32.6
Assistant Secretary for Policy, Planning and Program Evaluation								
International Affairs and Energy Emergencies—NA								
Total operating	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Technical personnel	0.0	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	0.0
Total direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Emergency Planning—NC								
Total operating	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Technical personnel	0.0	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	0.0	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Table 8.5
(continued)

	1993	1994	1995	1996	1997	1998	1999	2000
Policy, Analysis, and System Studies—PE								
Total operating	2.5	1.0	2.4	2.7	2.7	2.7	2.7	2.7
Technical personnel	9.1	6.9	7.3	7.5	7.5	7.5	7.5	7.5
Other direct personnel	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	9.2	6.9	7.3	7.5	7.5	7.5	7.5	7.5
Total Assistant Secretary for Policy, Planning and Program Evaluation								
Total operating	2.5	1.3	2.5	2.8	2.8	2.8	2.8	2.8
Technical personnel	9.1	7.1	7.5	7.7	7.7	7.7	7.7	7.7
Other direct personnel	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	9.2	7.1	7.5	7.7	7.7	7.7	7.7	7.7
Office of the Associate Deputy Secretary for Field Management								
In-House Energy Management—WB								
Total operating	0.4	0.4	0.9	0.3	0.3	0.3	0.3	0.3
Construction	0.4	2.1	0.0	0.0	0.0	0.0	0.0	0.0
Total program	0.8	2.5	0.9	0.3	0.3	0.3	0.3	0.3
Technical personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	0.9	2.1	2.0	1.2	1.2	1.2	1.2	1.2
Total direct personnel	0.9	2.1	2.0	1.2	1.2	1.2	1.2	1.2
Total Office of Assistant Deputy Secretary for Field Management								
Total operating	0.4	0.4	0.9	0.3	0.3	0.3	0.3	0.3
Construction	0.4	2.1	0.0	0.0	0.0	0.0	0.0	0.0
Total program	0.8	2.5	0.9	0.3	0.3	0.3	0.3	0.3
Technical personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	0.9	2.1	2.0	1.2	1.2	1.2	1.2	1.2
Total direct personnel	0.9	2.1	2.0	1.2	1.2	1.2	1.2	1.2
Federal Energy Regulatory Commission								
Federal Energy Regulatory Commission—VR								
Total operating	1.0	0.5	1.3	1.3	1.3	1.3	1.3	1.3
Technical personnel	2.4	5.2	6.6	5.9	5.9	5.9	5.9	5.9
Other direct personnel	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	2.4	6.0	6.6	5.9	5.9	5.9	5.9	5.9
Total Federal Energy Regulatory Commission								
Total operating	1.0	0.5	1.3	1.3	1.3	1.3	1.3	1.3
Technical personnel	2.4	5.2	6.6	5.9	5.9	5.9	5.9	5.9
Other direct personnel	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	2.4	6.0	6.6	5.9	5.9	5.9	5.9	5.9
Office of Economic Impact and Diversity								
Government Administration—Program Direction—WA								
Total operating	0.0	0.4	1.0	1.5	1.5	1.5	1.5	1.5
Technical personnel	0.0	0.2	0.4	0.5	0.5	0.5	0.5	0.5
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	0.0	0.2	0.4	0.5	0.5	0.5	0.5	0.5
Total Office of Economic Impact and Diversity								
Total operating	0.0	0.4	1.0	1.5	1.5	1.5	1.5	1.5
Technical personnel	0.0	0.2	0.4	0.5	0.5	0.5	0.5	0.5
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	0.0	0.2	0.4	0.5	0.5	0.5	0.5	0.5

Table 8.5
(continued)

	1993	1994	1995	1996	1997	1998	1999	2000
Assistant Secretary for Human Resources and Administration								
Scientific and Engineering Recruitment, T&D—TR								
Total operating	0.2	0.0	0.3	0.3	0.3	0.3	0.3	0.3
Technical personnel	0.3	0.9	1.0	1.0	1.0	1.0	1.0	1.0
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	0.3	0.9	1.0	1.0	1.0	1.0	1.0	1.0
Total Assistant Secretary for Human Resources and Administration								
Total operating	0.2	0.0	0.3	0.3	0.3	0.3	0.3	0.3
Technical personnel	0.3	0.9	1.0	1.0	1.0	1.0	1.0	1.0
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	0.3	0.9	1.0	1.0	1.0	1.0	1.0	1.0
DOE Funding from Energy Systems Central Organizations								
Uranium Enrichment—CD								
Total operating	4.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Technical personnel	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other direct personnel	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Uranium Enrichment Decontamination and Decommissioning Fund—EU								
Total operating	0.0	9.5	0.9	1.0	1.0	1.0	1.0	1.0
Technical personnel	0.0	26.0	26.0	26.0	26.0	26.0	26.0	26.0
Other direct personnel	0.0	5.4	5.4	5.5	5.5	5.5	5.5	5.5
Total direct personnel	0.0	31.4	31.4	31.5	31.5	31.5	31.5	31.5
Environmental Restoration and Waste Management—Defense—EW								
Total operating	106.8	68.5	75.0	75.0	75.0	75.0	75.0	75.0
Capital equipment	2.7	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Construction	5.3	5.0	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction	0.0	0.0	5.0	5.0	5.0	5.0	5.0	5.0
Total program	114.8	76.0	82.5	82.5	82.5	82.5	82.5	82.5
Technical personnel	281.1	237.1	240.0	240.0	240.0	240.0	240.0	240.0
Other direct personnel	63.3	39.0	40.0	40.0	40.0	40.0	40.0	40.0
Total direct personnel	344.4	277.0	280.0	280.0	280.0	280.0	280.0	280.0
Environmental Restoration and Waste Management—Non-Defense—EX								
Total operating	40.8	93.4	95.0	95.0	95.0	95.0	95.0	95.0
Capital equipment	(0.2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	12.4	7.5	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction	0.0	0.0	5.0	5.0	5.0	5.0	5.0	5.0
Total program	53.0	100.9	100.0	100.0	100.0	100.0	100.0	100.0
Technical personnel	105.7	221.4	221.0	221.0	221.0	221.0	221.0	221.0
Other direct personnel	27.3	57.0	60.0	60.0	60.0	60.0	60.0	60.0
Total direct personnel	133.0	278.4	281.0	281.0	281.0	281.0	281.0	281.0

Table 8.5
(continued)

	1993	1994	1995	1996	1997	1998	1999	2000
Total DOE Funding from Energy Systems Central Organizations								
Operating expense	151.9	171.4	170.9	171.0	170.0	170.0	170.0	170.0
Capital equipment	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Construction	17.7	12.5	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction	0.0	0.0	10.0	10.0	10.0	10.0	10.0	10.0
Total program	172.1	186.4	183.4	183.5	182.5	182.5	182.5	182.5
Technical personnel	387.2	484.5	487.0	487.0	487.0	487.0	487.0	487.0
Other direct personnel	90.7	102.3	105.4	105.5	105.5	105.5	105.5	105.5
Total direct personnel	477.9	586.8	592.4	592.5	592.5	592.5	592.5	592.5
Subtotal—DOE Programs								
Operating expense	482.3	478.1	552.2	586.4	609.3	611.9	611.9	611.9
Capital equipment	24.9	23.1	30.2	36.3	37.2	38.0	38.0	38.0
Construction	33.0	24.6	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction	0.0	0.0	22.8	128.7	183.8	417.2	532.7	534.1
Total	540.2	525.8	605.2	751.4	830.3	1067.1	1182.6	1184.0
Technical personnel	1439.0	1474.9	1485.7	1497.1	1528.6	1532.5	2246.0	2246.0
Other direct personnel	206.8	203.7	170.5	187.7	207.8	210.3	307.1	307.1
Total direct personnel	1645.8	1678.6	1656.2	1684.8	1736.4	1742.8	1742.8	1742.8
DOE Contractors and Operations Office								
Operating expense	25.0	15.9	19.7	19.3	19.3	19.3	19.3	19.3
Capital equipment	0.0	0.2	3.0	2.0	2.0	2.0	2.0	2.0
Total	25.0	16.1	22.7	21.3	21.3	21.3	21.3	21.3
Technical personnel	89.4	63.5	69.2	72.6	72.6	72.6	72.6	72.6
Other direct personnel	11.8	11.0	9.4	9.3	9.3	9.3	9.3	9.3
Total direct personnel	101.2	74.5	78.6	81.9	81.9	81.9	81.9	81.9
Cooperative R&D Agreements								
Operating expense	1.2	0.6	0.3	0.1	0.1	0.1	0.1	0.1
Technical personnel	4.3	3.6	1.8	0.3	0.3	0.3	0.3	0.3
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	4.3	3.6	1.8	0.3	0.3	0.3	0.3	0.3
Total DOE Programs								
Operating expense	508.3	494.6	572.2	605.8	628.7	631.3	631.3	631.3
Capital equipment	24.9	23.3	33.2	38.3	39.2	40.0	40.0	40.0
Construction	33.0	24.6	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction	0.0	0.0	22.8	128.7	183.8	417.2	532.7	534.1
Total	566.2	542.5	628.2	772.8	851.7	1088.5	1204.0	1205.4
Technical personnel	1532.7	1542.0	1556.7	1570.0	1601.5	1605.4	1605.4	1605.4
Other direct personnel	218.6	214.7	179.9	197.0	217.1	219.6	219.6	219.6
Total direct personnel	1751.3	1861.3	1736.6	1767.0	1818.6	1825.0	1825.0	1825.0
Work for others								
Nuclear Regulatory Commission								
Operating expense	18.4	19.3	20.6	20.3	20.3	20.3	20.3	20.3
Capital equipment	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total	18.5	19.4	20.6	20.3	20.3	20.3	20.3	20.3
Technical personnel	72.1	80.9	75.2	73.6	73.6	73.6	73.6	73.6
Other direct personnel	3.9	4.5	3.8	5.9	5.9	5.9	5.9	5.9
Total direct personnel	76.0	85.4	79.0	79.5	79.5	79.5	79.5	79.5

Table 8.5
(continued)

	1993	1994	1995	1996	1997	1998	1999	2000
Department of Defense								
Operating expense	34.0	23.5	26.0	28.0	28.0	28.0	28.0	28.0
Capital equipment	4.2	3.9	3.9	1.7	1.7	1.7	1.7	1.7
Total	38.2	27.4	29.9	29.7	29.7	29.7	29.7	29.7
Technical personnel	128.0	121.5	120.8	118.6	118.6	118.6	118.6	118.6
Other direct personnel	14.9	20.1	11.6	6.0	6.0	6.0	6.0	6.0
Total direct personnel	142.9	141.6	132.4	124.6	124.6	124.6	124.6	124.6
National Aeronautics and Space Administration								
Operating expense	4.7	5.9	5.2	7.9	7.9	7.9	7.9	7.9
Technical personnel	7.1	12.9	12.0	12.8	12.8	12.8	12.8	12.8
Other direct personnel	0.1	0.3	3.9	2.6	2.6	2.6	2.6	2.6
Total direct personnel	7.2	13.2	15.9	15.4	15.4	15.4	15.4	15.4
Department of Health and Human Services								
Operating expense	3.8	2.6	4.6	4.3	4.3	4.3	4.3	4.3
Capital equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	3.8	2.6	4.6	4.3	4.3	4.3	4.3	4.3
Technical personnel	17.1	15.8	14.9	15.3	15.3	15.3	15.3	15.3
Other direct personnel	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	17.2	15.9	24.9	15.3	15.3	15.3	15.3	15.3
Environmental Protection Agency								
Operating expense	2.1	1.1	3.0	2.9	2.9	2.9	2.9	2.9
Technical personnel	10.2	10.4	12.2	10.2	10.2	10.2	10.2	10.2
Other direct personnel	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	10.3	10.5	12.2	10.2	10.2	10.2	10.2	10.2
National Science Foundation								
Operating expense	0.8	0.1	0.5	0.5	0.5	0.5	0.5	0.5
Technical personnel	4.2	3.2	2.1	1.8	1.8	1.8	1.8	1.8
Other direct personnel	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	4.3	1.4	2.1	1.8	1.8	1.8	1.8	1.8
Federal Emergency Management Agency								
Operating expense	1.7	2.0	2.9	2.2	2.2	2.2	2.2	2.2
Technical personnel	5.8	4.6	7.3	5.9	5.9	5.9	5.9	5.9
Other direct personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total direct personnel	5.8	4.6	7.3	5.9	5.9	5.9	5.9	5.9
Department of Transportation								
Operating expense	5.7	9.0	8.9	6.7	6.7	6.7	6.7	6.7
Capital equipment	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Total program	5.8	9.2	8.9	6.7	6.7	6.7	6.7	6.7
Technical personnel	12.9	17.4	20.2	19.5	19.5	19.5	19.5	19.5
Other direct personnel	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total direct personnel	12.9	17.5	20.3	19.6	19.6	19.6	19.6	19.6
Other Federal agencies								
Total operating	0.7	3.3	2.4	2.4	2.4	2.4	2.4	2.4
Capital equipment	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Total program	0.8	3.5	2.4	2.4	2.4	2.4	2.4	2.4
Technical personnel	14.3	10.9	8.9	5.6	5.6	5.6	5.6	5.6
Other direct personnel	1.6	0.3	0.3	0.0	0.0	0.0	0.0	0.0
Total direct personnel	15.9	11.2	9.2	5.6	5.6	5.6	5.6	5.6

Table 8.5
(continued)

	1993	1994	1995	1996	1997	1998	1999	2000
Electric Power Research Institute								
Operating expense	1.7	1.8	1.7	1.8	1.8	1.8	1.8	1.8
Technical personnel	8.0	7.6	7.0	7.8	7.8	7.8	7.8	7.8
Other direct personnel	0.3	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Total direct personnel	8.3	7.7	7.2	8.0	8.0	8.0	8.0	8.0
Other nonfederal agencies								
Total operating	2.0	5.2	1.7	1.7	1.7	1.7	1.7	1.7
Technical personnel	19.8	18.9	11.6	7.4	7.4	7.4	7.4	7.4
Other direct personnel	0.1	0.8	0.1	0.0	0.0	0.0	0.0	0.0
Total direct personnel	19.9	19.7	11.7	7.4	7.4	7.4	7.4	7.4
Total Work for Others								
Total operating	75.6	73.8	77.5	78.7	78.7	78.7	78.7	78.7
Capital equipment	4.5	4.4	3.9	1.7	1.7	1.7	1.7	1.7
Total	80.1	78.2	81.4	80.4	80.4	80.4	80.4	80.4
Technical personnel	299.5	304.1	292.2	278.5	278.5	278.5	278.5	278.5
Other direct personnel	21.2	26.6	20.0	14.8	14.8	14.8	14.8	14.8
Total direct personnel	320.7	330.7	312.2	293.3	293.3	293.3	293.3	293.3
Total Program Resources								
Operating expense	584.1	568.4	649.7	684.5	707.9	710.0	710.0	710.0
Capital equipment	29.4	27.7	37.1	40.0	40.9	41.7	41.7	41.7
Construction	33.0	24.6	0.0	0.0	0.0	0.0	0.0	0.0
Proposed construction	0.0	0.0	22.8	128.7	183.8	417.2	532.7	534.1
Total	646.5	620.7	709.6	853.2	932.6	1168.9	1284.4	1285.8
Technical personnel	1832.2	1846.1	1848.9	1848.5	1880.0	1883.9	1883.9	1883.9
Other direct personnel	239.8	241.3	199.9	211.8	231.9	234.4	234.4	234.4
Total direct personnel	2072.0	2087.4	2048.8	2060.3	2111.9	2118.3	2118.3	2118.3

Table 8.6
Subcontracting and procurement by fiscal year
($ in millions—obligated)

	1993	1994	1995[a]	1996[a]
Universities	15.6	17.0	17.2	17.3
All others	164.6	160.2	164.2	167.4
Transfers to other DOE facilities	3.0	3.1	3.2	3.2
Total external subcontracts and procurements	183.2	180.3	184.6	187.9

[a]Estimated.

Table 8.7
Estimated small and disadvantaged business procurement by fiscal year
($ in millions—BA)

	1993	1994
Total small and disadvantaged business	79.6	88.8
Disadvantaged business	14.9	21.5
Women- and minority-owned business	13.5	15.1
Labor surplus (economically depressed area)	25.9	29.3

Appendix

Site and Facilities Data

ORNL occupies ~3 million gross square feet (GSF) of building space at the main Bethel Valley site and the Melton Valley site to the south, 938,000 GSF of building space at the Oak Ridge Y-12 Plant, and ~14,000 GSF of space at the Oak Ridge K-25 Site. ORNL also leases over 89,000 GSF of space off site. Figures A.1–A.6 illustrate the current distribution, use, age, condition, and size of ORNL buildings. Figure A.7 shows the level of capital funding for nonenvironmental capital improvements at ORNL over the past several years.

Table A.1 lists estimated facility replacement values. These estimates are based on active functions and do not include replacement of obsolete facilities or costs associated with decontamination and decommissioning (D&D) of existing facilities. Table A.2 lists ORNL's capital equipment investment.

Table A.3 lists major construction projects for the planning period. This list includes the Advanced Neutron Source, the Center for Biological Sciences, and other facilities needed to support ORNL missions.

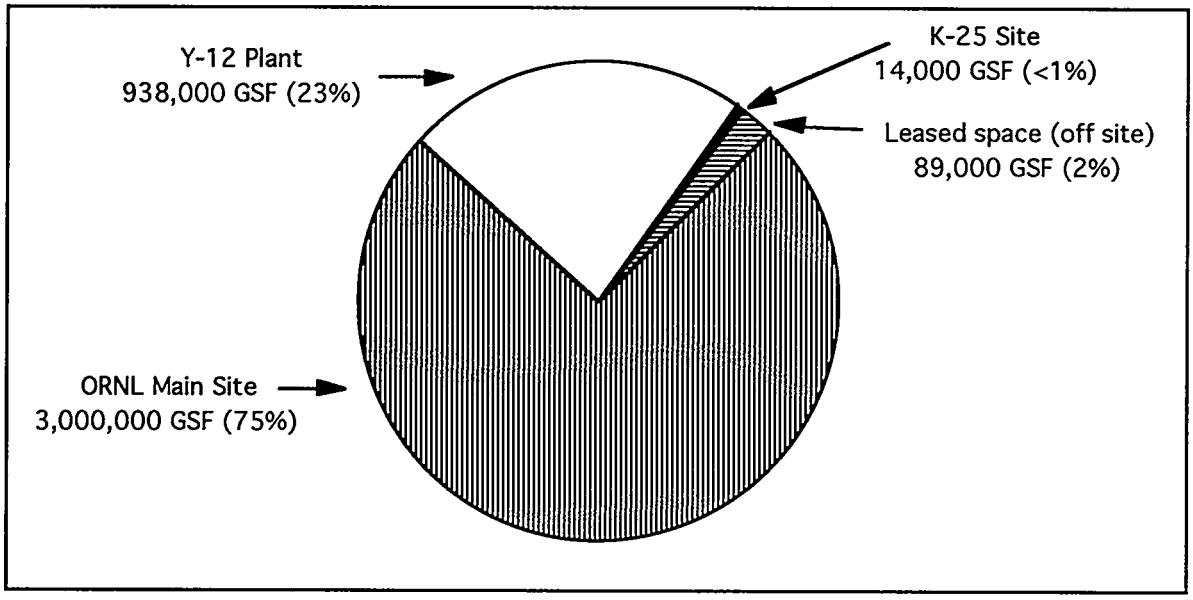


Figure A.1
Laboratory space distribution—location and building area in gross square feet (GSF).

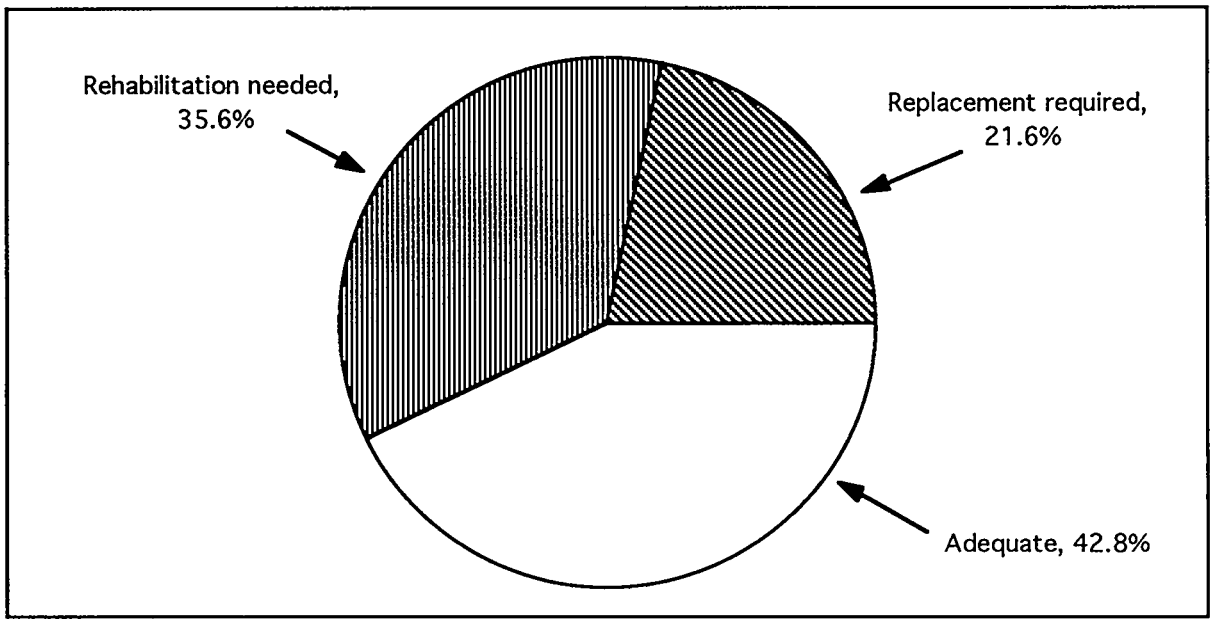


Figure A.2
Condition of Laboratory space.

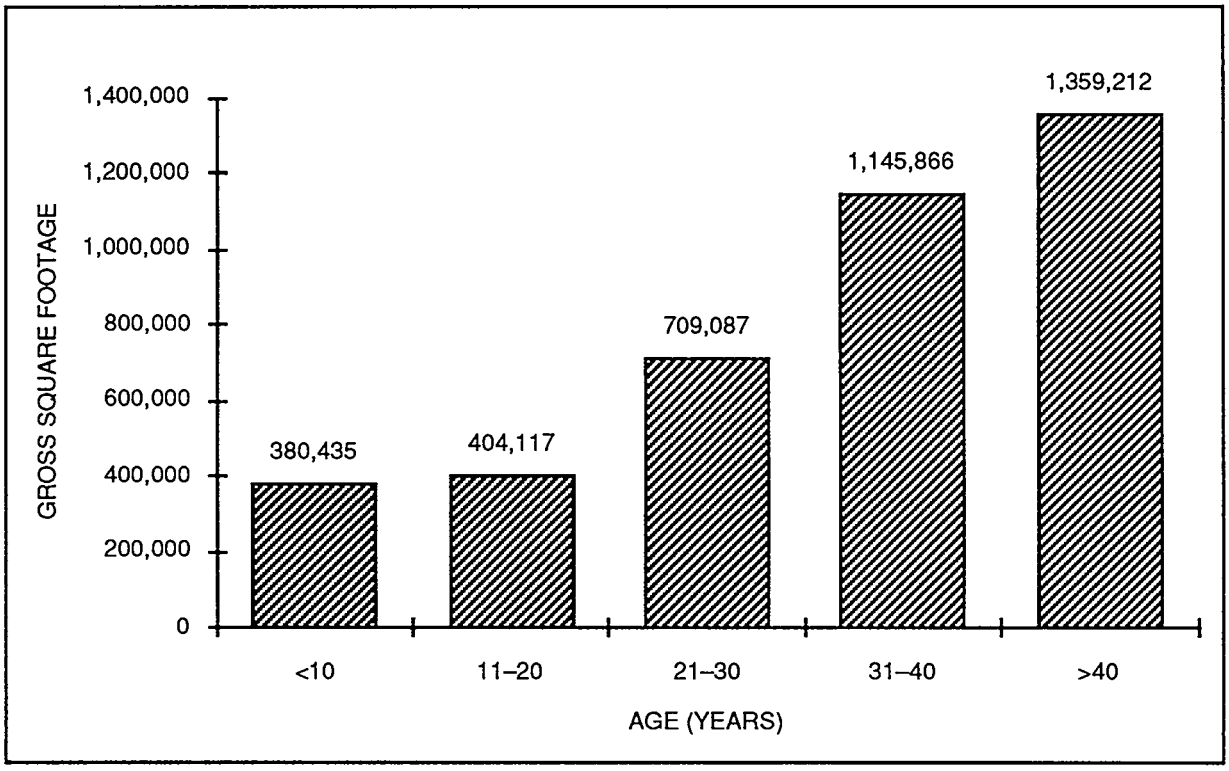


Figure A.3
Gross square footage of Laboratory buildings, categorized by age. Of 3,998,717 total gross square feet (GSF), 2,505,078 GSF (62.6% of the total) is over 30 years old. The average age is 34.7 years.

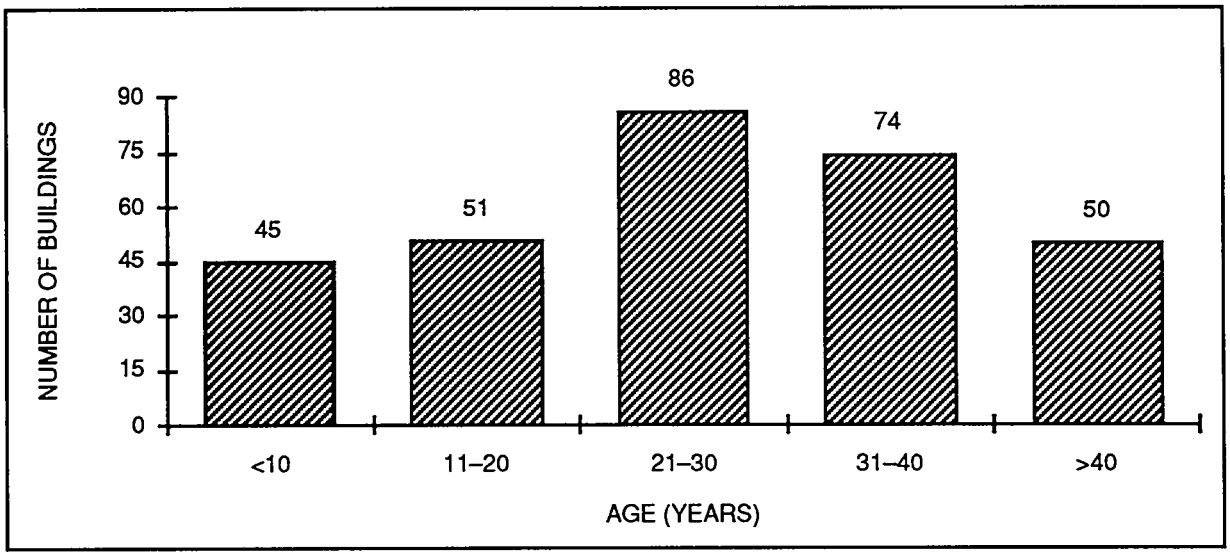


Figure A.4
Number of Laboratory buildings, categorized by age. Of 306 buildings, 124 (30%) are over 30 years old. The average building age is 28.2 years.

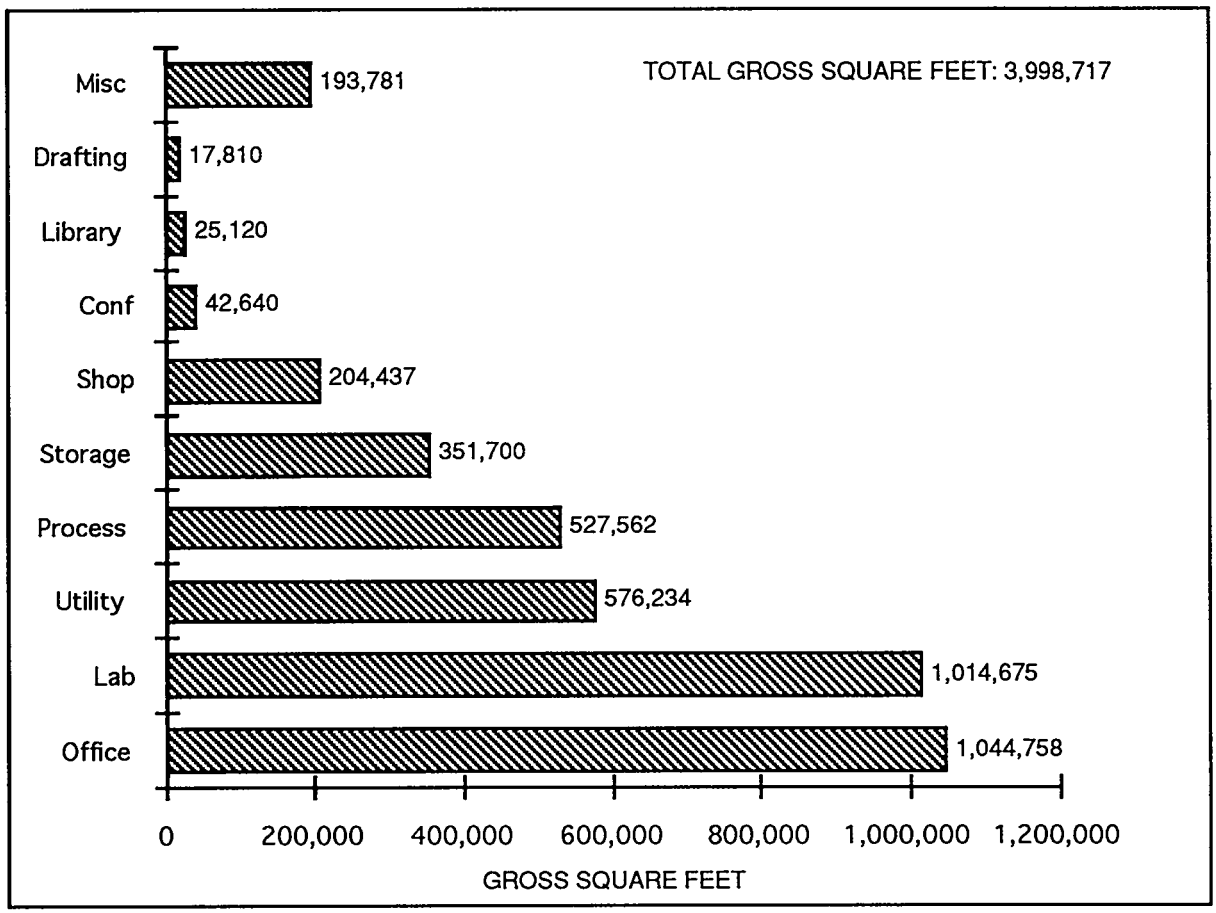


Figure A.5
Use of space.

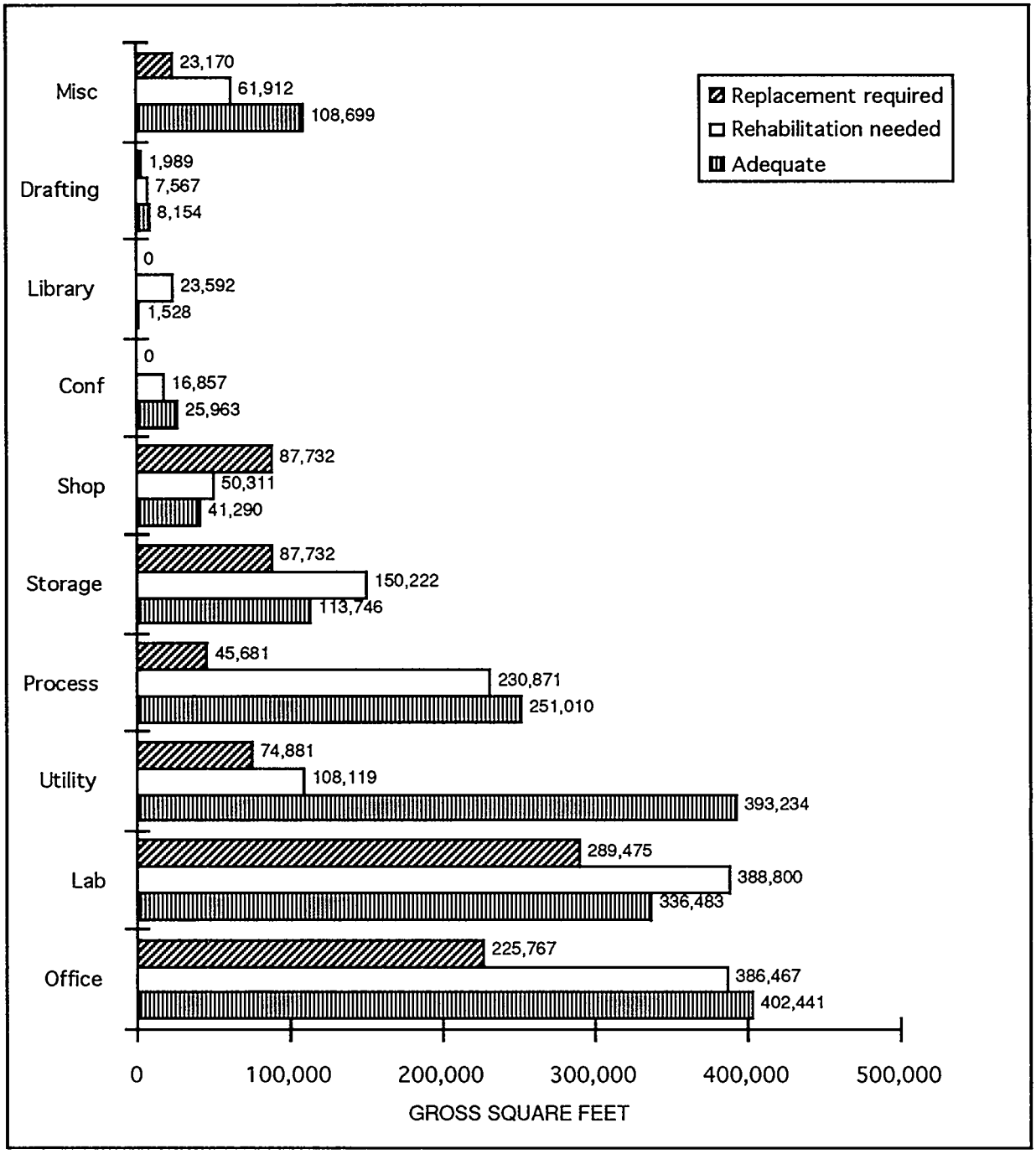


Figure A.6
Condition of space, categorized by use.

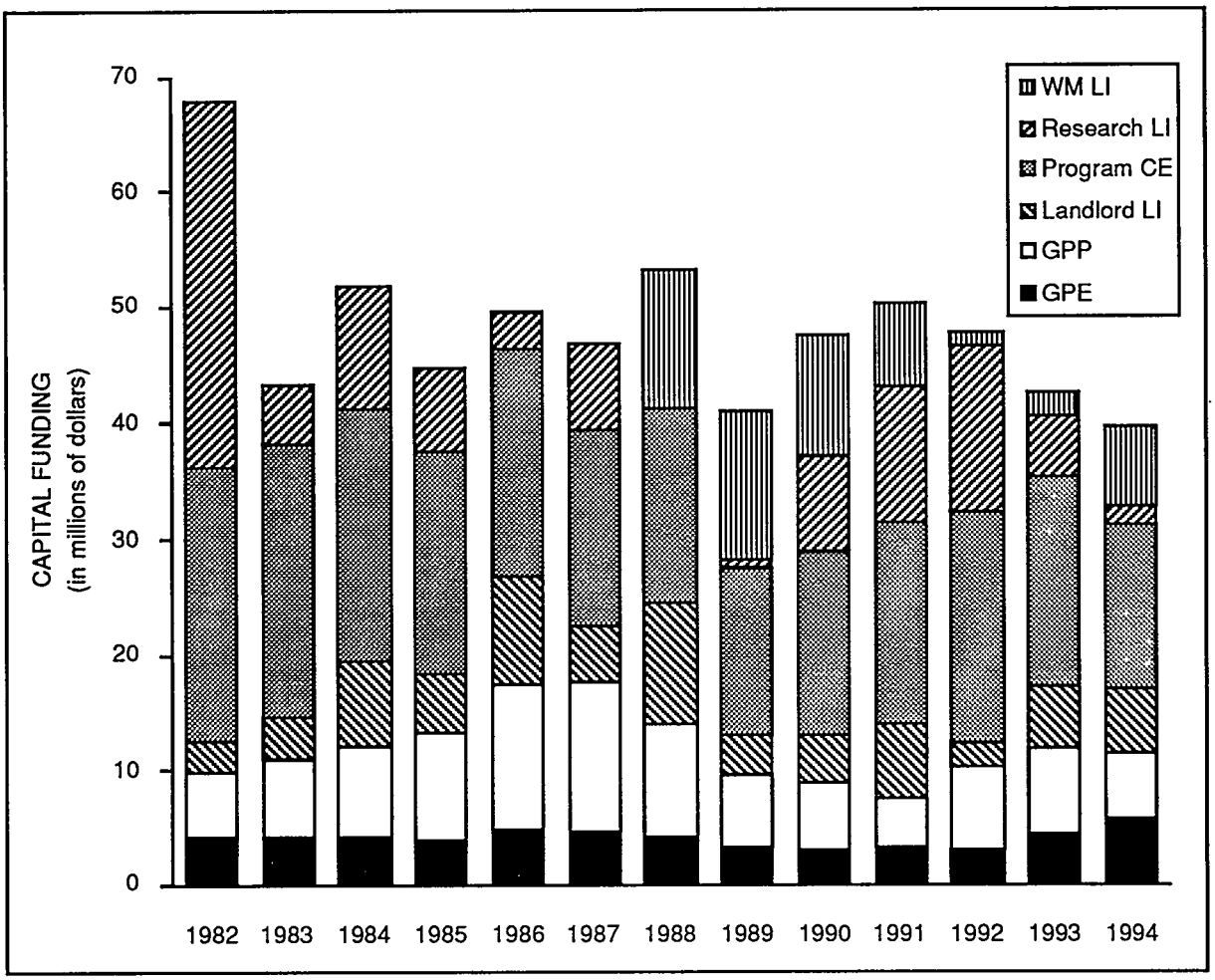


Figure A.7
Funding levels for nonenvironmental capital improvements at ORNL. GPE = general-purpose equipment. GPP = general plant project. LI = line item. CE = capital equipment. WM = waste management. Dollar amounts are by fiscal year (not adjusted for inflation).

Table A.1
Estimated facilities replacement values[a]

Facilities type	Replacement cost range[b] Lower	Upper
Buildings and structures	730	1,032
Reactors	1,300	1,650
Process facilities	480	725
Accelerators	285	430
Utility systems	240	350
Roads, bridges, and parking	143	176
Security facilities	6	11
Automatic data-processing equipment	66	93
Motor vehicles	11	17
Heavy equipment	6	11
Other equipment and facilities	33	55
Subtotal, fixed-price construction	3,300	4,550
Engineering (35%)	1,163	1,593
Construction support services (20%)	660	910
Operational readiness review (2.5%)	82	114
Construction manager (15%)	495	683
Subtotal	5,700	7,850
Contingency (40%)	2,300	3,150
Total	8,000	11,000

[a]DOE estimates the replacement value of ORNL facilities at $2.5 billion.
[b]In millions of FY 1993 dollars.

Table A.2
Capital equipment inventory

Functional unit	Description	Cost ($ in thousands)
50	Heavy Mobile Equipment	3,626
51	Hospital & Medical	417
52	Lab Equipment	122,950
53	Motor Vehicles & Aircraft	9,573
54	Office Furniture	3,216
55	Process Equipment	25,036
57	Reactors and Accelerator	1,650
58	Security /Protection Equipment	308
59	Shop Equipment	19,403
60	Automated Data Processing	55,367
61	Portable Communications Electronic Equipment	449
79	Miscellaneous Equipment	3,775
	Total	245,770

Table A.3
Major construction projects[a]
($ in millions)

	Funded construction		Budgeted construction	Proposed construction					
	1993	1994	1995	1996	1997	1998	1999	2000	TEC[b]
Research program line-item projects[c]									
Upgrade neutron scattering instrumentation			3.8	5.3	4.9				14.0
Advanced Neutron Source (construction)				98.3	203.5	365.3	522.7	524.1	2119.6
Center for Biological Sciences				18.0	43.0	41.9			102.9
Institute for Study of Advanced Materials						2.0	8.0	8.0	18.0
Materials Research and Development Laboratory				1.0	2.0	20.0	40.0	32.0	95.0
Upgrade Radiochemical Development Facility ventilation and containment				3.2	8.0	17.0	15.0		43.2
Earth Systems Facility					2.0	10.0	7.6		19.6
Biological Imaging and Photonics Laboratory					1.5	6.5			8.0
Waste management projects									
Bethel Valley LLW-CAT system upgrade (WBS 3.37)		6.5	17.0	6.0	0.5				65.0
Upgrade process waste treatment system		9.6							14.3
Melton Valley LLW-CAT system upgrade (WBS 3.45)	15.9	11.5	9.1						41.0
Upgrade sanitary sewer system	2.0	7.0	7.0						16.0
Bethel Valley FFA upgrades		3.6	7.0	8.9	1.0				20.5
Waste Characterization and Certification Facility (WBS 4.48)			2.0	5.5	8.5	2.0			18.0
MVST capacity increase		9.4	22.0	11.0	5.6				48.0
Process Waste Treatment Facility				2.0	13.0	5.0	2.0		22.0
Retrievable Cask Storage Bunker				2.0	2.0	2.0			6.0
SWSA 8				2.0	2.0	2.0			14.0
Interim Waste Management Facility II					1.0	2.0			3.0
Waste Handling and Packaging Plant						43.1	54.5		320.0

Table A.3
(continued)

	Funded construction		Budgeted construction	Proposed construction					
	1993	1994	1995	1996	1997	1998	1999	2000	TEC[b]
Multiprogram general-purpose facilities (KG)									
Buildings/facilities revitalization									
A. Replace substandard housing									
Measurement and Controls Support Facility	0.5								4.73
Central Research and Support Building				5.0	8.0	2.6			15.6
Environmental, Safety, and Health Compliance and Training Facility				6.1	8.4				14.5
Central Maintenance Support and Quality Testing Facility					3.0	9.0	6.0		18.0
Decontamination laundry						2.0	8.0	1.0	11.0
Safeguards and Security Building							3.0	7.1	16.0
B. Renovate serviceable structures									
Replace deteriorated roofing, priority 1		3.2	3.8	5.1	3.9				16.0
Replace deteriorated roofing, priority 2				4.0	8.0	7.0			19.0
Replace deteriorated roofing, priority 3						4.0	7.0	6.0	17.0
Upgrade building HVAC systems, ORNL at the Y-12 Plant						4.0	2.0		6.0
Upgrade building HVAC systems, east end						6.0	8.0	6.0	20.0
Upgrade building HVAC systems, west end							5.0	6.3	15.0
Upgrade HVAC systems, Building 2026				2.8	7.6	7.6	2.0		20.0
Restore Central Research Complex							15.0	39.0	100.0
C. New capabilities									
Advanced Computing Technology Center						3.0	8.0	6.5	17.5
Center for Education and Technology Transfer							4.0	6.2	13.6
Environmental, safety, and health protection									
A. Environmental protection									
Steam plant environmental improvements						4.0	10.0	6.0	20.0

Table A.3
(continued)

	Funded construction		Budgeted construction	Proposed construction					
	1993	1994	1995	1996	1997	1998	1990	2000	TEC[b]
B. Safety									
OSHA compliance facility upgrades				2.0	5.0	4.0			11.0
C. Utility restorations									
Upgrade steam distribution system, west end	5.2	2.7							9.0
Upgrade central chilled water plant				2.0	2.0				4.0
Upgrade water system					4.0	12.0	12.0	3.0	31.0
Upgrade primary electrical distribution system						3.0	8.0	7.5	18.5

[a]Construction data as of September 1994.
[b]Total estimated cost.
[c]Does not include accelerator and reactor improvements and modifications projects.

Technology Transfer Data

ORNL's guest population, shown in Fig. A.8 for 1988 through 1993, remains high. The distribution of guests is shown in Table A.4.

Ten designated user facilities were operated in FY 1993, including the Oak Ridge Centers for Manufacturing Technology at the Oak Ridge Y-12 Plant. (Operation of the Holifield Radioactive Ion Beam Facility is expected to commence in late FY 1995.) Statistics for use in FY 1993 are shown in Table A.5. In FY 1993, 760 scientists representing 233 institutions conducted experiments at ORNL user facilities; 33% were university scientists. Growth in the industrial user population continued, with 102 experimenters from 62 companies in FY 1993. This is a 56% increase in the number of industrial researchers from FY 1992.

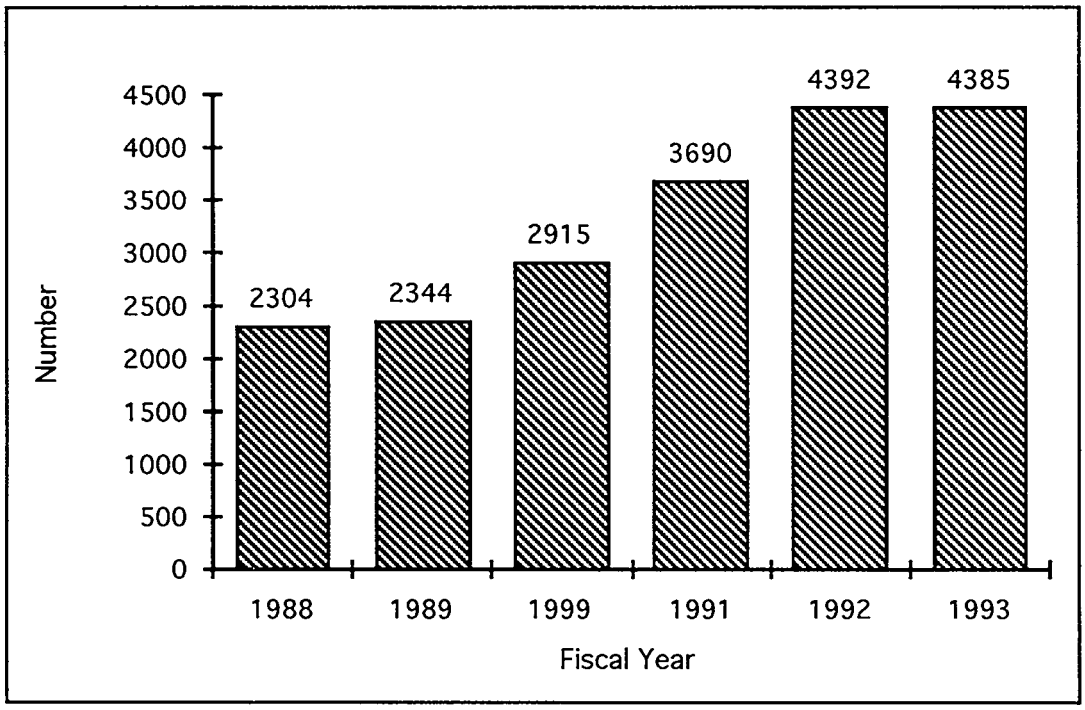


Figure A.8
ORNL guest assignments, 1988–1993.

Table A.4
Number of guest assignments at ORNL[a]

	1988	1989	1990	1991	1992	1993
University	1428	1395	1551	1696	2022	2119
Industry	689	736	972	1408	1723	1557
Federal agencies	40	52	52	78	61	66
Foreign institutions	59	48	84	72	78	56
Other	88	113	256	436	508	587
Total	2304	2344	2915	3690	4392	4385

[a]Guests are nonemployees who come on site to conduct research, consult, or perform other services. Users are included in the totals; e.g., in FY 1991, 674 of the 3690 guests were users.

Table A.5
Experimenters at ORNL's designated user research facilities in FY 1993

	U.S. government laboratory[a]			University			Industry			International			Total		
	Exp.[b]	Org.[c]	% of use	Exp.	Org.	% of use	Exp.	Org.	% of use	Exp.	Org.	% of use	Exp.	Org.	User days
National Environmental Research Park (NERP)[d]	85	6	62.5	34	17	33.5	9	4	3.5	1	1	0.5	129	28	2,935
High Temperature Materials Laboratory (HTML)	101	1	70.5	47	20	9.8	46	30	19.7	0	0	0	194	51	13,714
Surface Modification and Characterization Research Center (SMAC RC)	34	3	53.4	46	24	34.1	4	4	0.6	9	7	11.9	93	38	2,381
Shared Research Equipment Program (SHARE)	36	2	75.6	26	11	17.6	2	2	1.2	4	4	5.6	68	19	859
Neutron Scattering Research Facilities (NSRF)	45	6	31.5	57	21	24.5	26	12	9.6	54	20	34.4	182	59	3,230
EN Tandem Van de Graaff	7	1	36.0	20	5	62.0	0	0	0	2	2	2.0	29	8	980
Oak Ridge Electron Linear Accelerator (ORELA)	20	4	74.2	3	2	7.3	2	1	12.2	3	2	6.3	28	9	6,957
Bioprocessing Research Facility	6	1	54.8	7	5	40.8	2	1	4.4	0	0	0	15	7	272
Buildings Technology Center	5	1	30.5	4	3	23.0	10	7	24.7	1	1	21.8	20	12	1,134
Oak Ridge Centers for Manufacturing Technology (ORCMT)[e]	0	0	0	1	1	81.1	1	1	18.9	0	0	0	2	2	37
Total	339	25	48.9	245	109	33.4	102	62	9.5	74	37	8.2	760	233	32,499

[a]Includes 271 ORNL users (35.6% of use).

[b]Exp. = number of experimenters.

[c]Org. = number of organizations.

[d]The totals do not include over 20,000 individuals who participated in the Ecological and Physical Sciences Study Center and the High School Honors Program for a total of 10,434 user hours in FY 1993.

[e]The Oak Ridge Centers for Manufacturing Technology opened as a designated user facility in September 1993.

ORNL's participation in CRADAs continues to increase. Between 1991, when the program was initiated, and February 1994, 112 CRADAs were approved (including several joint CRADAs with the Oak Ridge Y-12 Plant.)

Science and Mathematics Education Data

ORNL provides educational opportunities to students and teachers at all levels, from preschool through postgraduate education. Statistics for use of ORNL's programs are presented in Table A.6.

Table A.6
Participation in science and math education programs

	FY 1993			FY 1994		
	Total	Minorities	Women	Total	Minorities	Women
Precollege student programs						
Adventures in Math/Science	191	100	95	100	54	47
Adventures in Supercomputing	296	30	134	528	45	241
ARC Honors Academy	35	3	17	33	2	18
DOE Honors Workshop	59	12	41	57	11	38
Clinch River Environmental Studies Organization	20	1	12	22	1	13
NAACP Scholars	—	—	—	17	17	10
Oak Ridge Educational Network	—	—	—	800	*a*	*a*
Project SEED/Hispanic SEED	18	12	13	15	10	10
Regional Science Bowls	295	35	46	270	30	65
Saturday Academy of Computing and Mathematics	45	2	21	28	2	13
Special Honors Study	8	1	1	2	0	1
Spectacles Camp, Wesleyan College	68	10	68	22	3	22
Ecological and Physical Sciences Study Center	20,897	1,960	10,400	23,734	2,100	16,800
Summer Science Experience	77	7	35	46	4	20
Women in Science/Technology Conference	110	10	110	100	12	100
Junior Science/Humanities	135	10	69	129	10	66
Special Programs	425	105	208	450	102	220
Total	22,679	2,298	11,270	26,353	2,403	17,684

Table A.6
(continued)

	FY 1993			FY 1994[a]		
	Total	Minorities	Women	Total	Minorities	Women
Precollege teacher programs						
Academy for Math/Science	82	9	55	80	7	53
Administrators Workshop	47	4	20	30	2	17
Adventures in Supercomputing	25	2	17	37	3	25
ARC Honors Academy	14	0	7	14	0	6
DOE Honors Workshop	5	1	3	4	1	2
DOE Teacher Research Associates	47	10	18	42	8	20
DOE Lyndhurst Fellows	12	0	8	12	0	4
Elementary Leadership Institute (NSF)	25	4	22	24	4	22
Hands-On Science Workshops	45	3	41	22	2	18
Project SMART	75	0	68	90	2	73
Science Enrichment	54	19	44	10	2	7
Saturday Academy of Computing and Mathematics	12	0	6	6	0	4
Teacher In-Service Training	362	334	229	354	40	221
Tri-State Educational Consortium	—	—	—	18	0	12
Total	805	386	538	743	71	484
Undergraduate programs						
Alliance for Minority Participation	—	—	—	6	4	6
Buildings Technology Internships	—	—	—	3	3	2
Cooperative Education	61	17	19	67	22	23
Customized Internships (HBCU)	2	2	2	2	2	2
DOE Science Semester (SERS)	72	10	37	77	11	29
DOE Summer Practicums	5	2	2	0	0	0
EMCOM	18	16	11	22	22	15
Graduate School Fair	—	—	—	325	60	180
GLCA/ACM Science Semester	16	0	6	25	8	7
Health/Environment (HBCU)	10	10	4	5	5	1
Nuclear Energy (HBCU)	4	4	3	6	6	3
Nuclear Regulatory (HBCU)	—	—	—	12	12	2
Professional Internship Program	64	5	21	72	11	28
SERS Summer Program	30	2	17	35	5	13
Science and Technology Alliance	5	5	0	13	12	5
Service Academies Research	0	0	0	0	0	0
Student Research Participation	30	3	13	25	2	9
Summer Technical Internship	106	32	47	44	8	19
Technology Internship Program	33	3	11	42	3	19
University of Puerto Rico	7	7	4	2	2	0
Women in Science Conference	192	19	187	200	25	198
Total	655	137	384	983	223	561

Table A.6
(continued)

	FY 1993			FY 1994[a]		
	Total	Minorities	Women	Total	Minorities	Women
Graduate programs						
DOE Fellowship Practicums	4	0	0	5	0	1
Graduate Education for Minorities (GEM)	5	5	1	3	3	1
Graduate Student Research	25	2	8	36	3	7
High Temperature Materials Fellowships	2	0	0	4	0	0
Laboratory Graduate Research	6	0	2	9	0	1
Law Internship Program	12	0	6	7	1	3
Materials Research (AIC)	4	2	2	2	2	0
Nuclear Energy Training	1	1	0	0	0	0
Professional Internship Program	27	3	13	48	4	15
Research Travel Contracts	13	0	1	10	0	5
Service Academies Research	0	0	0	0	0	0
Total	99	13	33	124	13	33
Postgraduate programs						
DOE Postdoctoral Programs						
Distinguished Postdoctoral	—	—	—	2	0	0
Fusion Energy	3	0	0	1	0	0
Global Change	3	0	0	4	0	0
Hollaender	7	0	2	6	0	2
Human Genome	1	0	0	2	0	0
ORNL Postdoctoral Research	136	3	22	193	5	31
Postgraduate Research Training Program	35	2	8	37	2	14
Wigner Postdoctoral Fellows	2	1	2	5	1	1
Total	187	6	34	250	8	48
Faculty programs						
Environmental Management (EMCOM)	7	6	2	1	1	0
Faculty Research Participation	44	9	2	40	9	12
Great Lakes/Midwest Colleges	2	0	1	3	0	1
HBCU Faculty Research	7	7	1	14	14	2
Minority Institution Research Travel	10	10	3	8	8	1
Research Travel	75	34	18	36	8	2
Science and Technology Alliance	6	3	1	7	3	2
Total	151	69	28	109	43	20

[a]Not determined.

Human Resources Data

Tables A.7 and A.8 present statistics on the number of minority staff members at ORNL in 1988 and 1993. Table A.9 contains information on the composition of ORNL staff.

Table A.7
Equal employment opportunity statistics for 1988

Occupational code	Total (%)[a]		Minority total (%)		White (%)		Black (%)		Hispanic (%)		Native American (%)		Asian/Pacific Islander (%)	
	M[b]	F[c]	M	F	M	F	M	F	M	F	M	F	M	F
Officials and managers[d]	393 (93.3)	28 (6.7)	18 (4.3)	1 (0.2)	375 (89.0)	27 (6.4)	14 (3.3)	1 (0.2)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	4 (0.9)	0 (0.0)
Professional staff	1506 (84.0)	287 (16.0)	123 (6.9)	35 (2.0)	1383 (77.1)	252 (14.0)	34 (1.9)	18 (1.0)	14 (0.8)	1 (0.05)	1 (0.05)	1 (0.05)	74 (4.1)	15 (0.8)
Technicians	442 (76.2)	138 (23.8)	31 (5.3)	14 (2.4)	411 (70.9)	124 (21.4)	23 (4.0)	11 (1.9)	8 (1.4)	1 (0.2)	0 (0.0)	0 (0.0)	0 (0.0)	2 (0.3)
All other	953 (57.2)	712 (42.8)	135 (8.1)	101 (6.1)	818 (49.1)	611 (36.7)	130 (7.8)	93 (5.6)	2 (0.1)	3 (0.2)	2 (0.1)	1 (0.06)	1 (0.06)	4 (0.24)
Total	3294 (73.9)	1165 (26.1)	307 (6.9)	151 (3.4)	2987 (67.0)	1014 (22.7)	201 (4.5)	125 (2.8)	24 (0.5)	5 (0.1)	3 (0.06)	2 (0.04)	79 (1.8)	21 (0.5)

[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 A.8

Equal employment opportunity statistics for 1993

Occupational code	Total (%)[a]		Minority total (%)		White (%)		Black (%)		Hispanic (%)		Native American (%)		Asian/Pacific Islander (%)	
	M[b]	F[c]	M	F	M	F	M	F	M	F	M	F	M	F
Officials and managers[d]	428 (91.8)	38 (8.1)	25 (5.4)	3 (0.6)	403 (86.5)	35 (7.5)	21 (4.5)	2 (0.4)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	4 (0.9)	1 (0.2)
Professional staff														
Scientists and engineers	1373 (87.1)	203 (12.9)	120 (7.6)	22 (1.4)	1253 (79.5)	181 (11.4)	28 (1.8)	11 (0.7)	16 (1.0)	2 (0.1)	1 (0.06)	1 (0.06)	75 (4.8)	8 (0.5)
Computing and administrative	330 (58.8)	231 (41.2)	28 (5.0)	24 (4.3)	302 (53.8)	207 (36.9)	17 (3.0)	17 (3.0)	6 (1.1)	0 (0.0)	0 (0.0)	0 (0.0)	5 (0.9)	7 (1.2)
Technicians	341 (70.5)	143 (29.5)	21 (4.3)	16 (3.3)	320 (66.6)	127 (26.2)	16 (3.3)	12 (2.5)	5 (1.0)	0 (0.0)	0 (0.0)	1 (0.2)	0 (0.0)	3 (0.6)
All other	823 (50.3)	814 (49.7)	103 (6.3)	118 (7.2)	720 (44.0)	696 (42.5)	98 (6.0)	104 (6.4)	1 (0.06)	6 (0.4)	1 (0.06)	1 (0.06)	3 (0.1)	7 (0.4)
Total	3295 (69.8)	1429 (30.2)	297 (6.2)	183 (3.9)	2998 (63.5)	1246 (26.4)	180 (3.8)	146 (3.1)	28 (0.6)	8 (0.2)	2 (0.04)	3 (0.06)	87 (1.8)	26 (0.6)

[a]Percentage of total number of employees in occupational category.

[b]M = male.

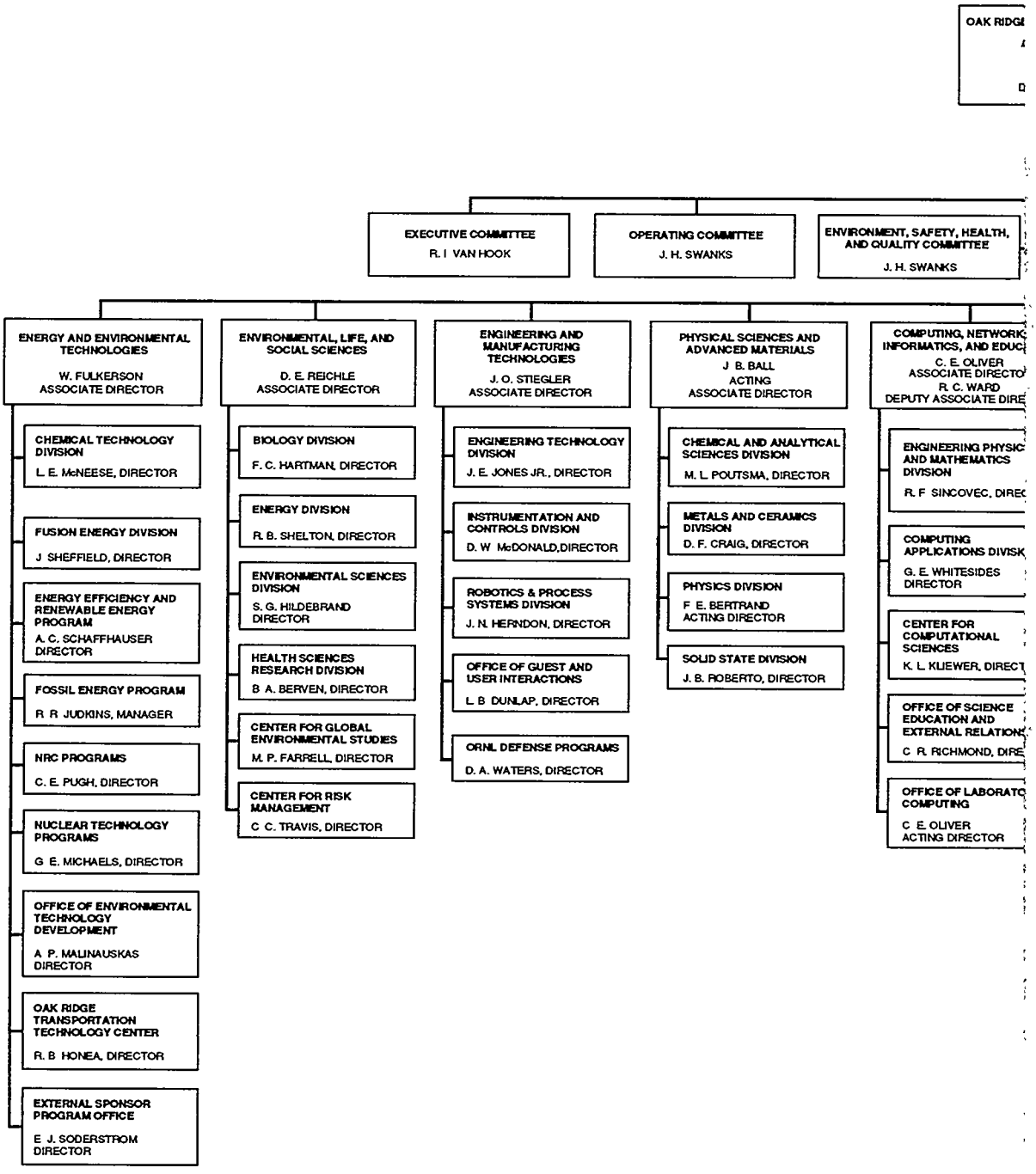
[c]F = female.

[d]As defined on Standard Form 100 (EEO-1), as required by 41 CFR 60-1.7(a).

Table A.9
ORNL staff composition (CY 1993)[a]

	Ph.D.	M.S.	B.S./B.A.	A.S.	Non-degreed	Total
			Professional staff			
Scientists	479	174	135	6	26	820
Engineers	295	271	293	16	76	951
Management/administrative	123	118	144	5	59	449
Other	31	99	116	17	150	413
Total professional staff	928	662	688	44	311	2633
			Support staff			
Technicians	0	8	89	125	284	506
Union employees (includes crafts, laborers, etc.)	0	1	11	29	970	1011
Administrative/clerical	0	5	71	66	653	795
Other (supervisors of union employees)	0	1	7	9	77	94
Total support staff	0	15	178	229	1984	2406
Total ORNL staff	928	677	866	273	2295	5039

[a]Includes full-time regular employees.



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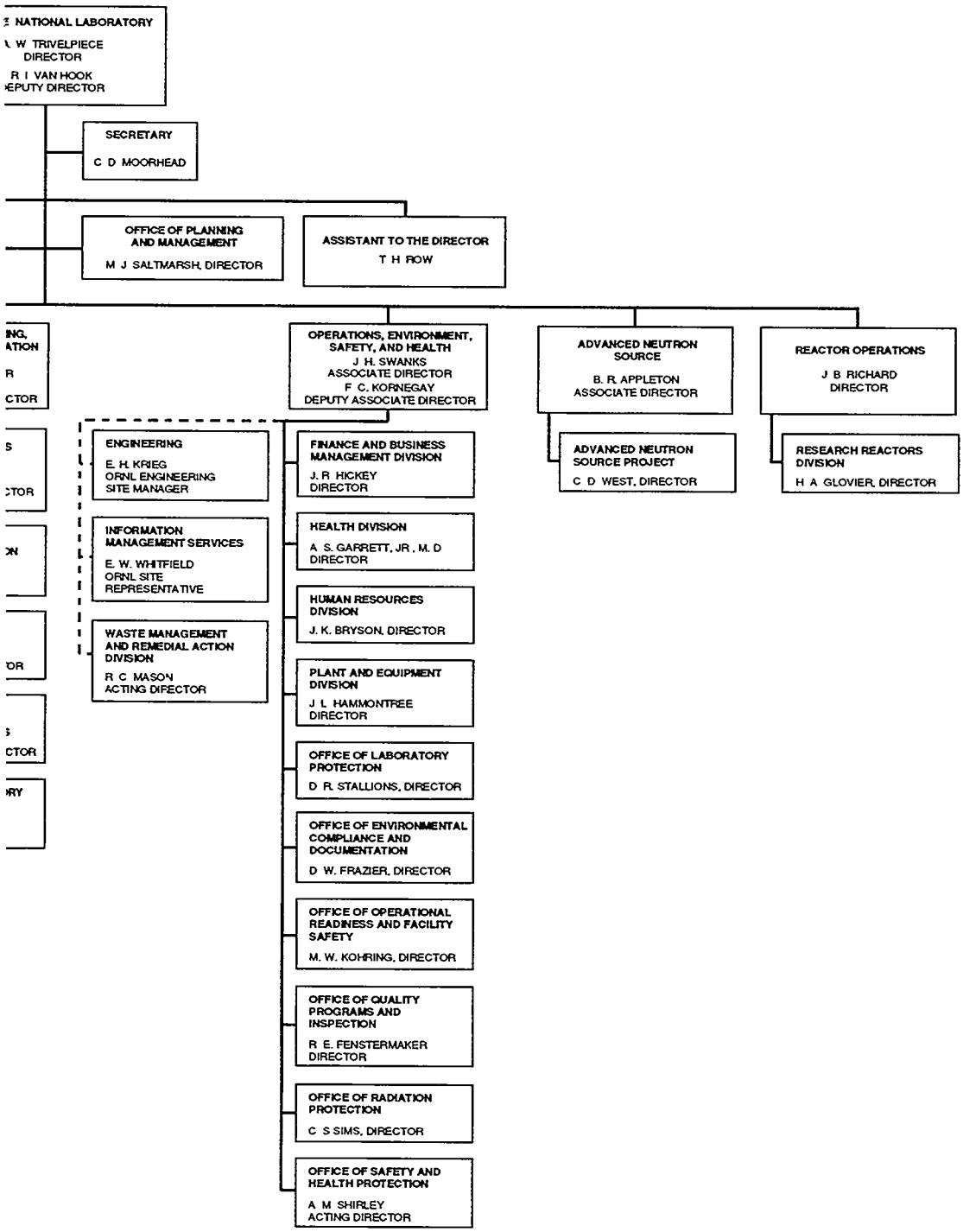

NATIONAL LABORATORY

TA ENERGY SYSTEMS, INC.

EFFECTIVE DATE: SEPTEMBER 1, 1994

MARTIN MARIETTA

Abbreviations

AA	affirmative action
ac	alternating current
AEOD	NRC Office of Analysis and Evaluation of Operational Data
AEP	Advanced Energy Projects
AFCESA	Air Force Civil Engineering Support Agency
AHAM	Association of Home Appliance Manufacturers
AIC	Advanced Industrial Concepts
AID	U.S. Agency for International Development
AiS	Adventures in Supercomputing
AMC	Air Mobility Command
AMSEC	Advanced Materials Science and Engineering Complex
AMTEX	American Textile Partnership
ANL	Argonne National Laboratory
ANS	Advanced Neutron Source
ARL	Army Research Laboratory
ARM	Atmospheric Radiation Measurement
ARPA	Advanced Research Projects Agency
ATF	Advanced Toroidal Facility
ATS	Advanced Turbine System
ATSDR	Agency for Toxic Substances and Disease Registry
B&W	Babcock and Wilcox
BA	budget authority
BES	Basic Energy Sciences
BFDP	Biofuels Feedstock Development Program
BLPT	beryllium lymphocyte proliferation test
BNL	Brookhaven National Laboratory
BRDC	Bioprocessing Research and Development Center
BRF	Bioprocessing Research Facility
BSR	Bulk Shielding Reactor
BTC	Buildings Technology Center
BWR	boiling-water reactor
C-CAP	Coastal Change Analysis Program
CAIS	Condition Assessment Information System
CAMP	Capital Asset Management Program
CANDU	Canadian deuterium-uranium reactor
CAS	Chemical Abstracts Service; Condition Assessment Survey
CBS	Center for Biological Sciences
CCII	Computational Center for Industrial Innovation
CCS	Center for Computational Sciences
CCTP	Clean Coal Technology Project
CD-ROM	compact disk–read-only memory
CDIAC	Carbon Dioxide Information Analysis Center
CDNSWC	Carderock Division, Naval Surface Warfare Center

CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERN	European Laboratory for Particle Physics (formerly Conseil Européen pour la Recherche Nucléaire)
CERR	Center for Excellence in Research Reactors
CESAR	Center for Engineering Systems Advanced Research
CET	Center for Environmental Technology
CFC	chlorofluorocarbon
CFCC	continuous fiber ceramic composite
CFR	Code of Federal Regulations
CGES	Center for Global Environmental Studies
CHAMMP	Computer Hardware, Advanced Mathematics, and Model Physics
CRADA	cooperative research and development agreement
CURE	Chemical Unit Record Estimates
D&D	decontamination and decommissioning
D-T	deuterium-tritium
DAAC	Distributed Active Archive Center
dc	direct current
DMS	DOE Division of Materials Science
DNA	deoxyribonucleic acid
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOE-BES	U.S. Department of Energy, Office of Basic Energy Sciences
DOE-DP	U.S. Department of Energy, Assistant Secretary for Defense Programs
DOE-EE	U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy
DOE-EH	U.S. Department of Energy, Assistant Secretary for Environment, Safety, and Health
DOE-EM	U.S. Department of Energy, Office of Environmental Management
DOE-ER	U.S. Department of Energy, Office of Energy Research
DOE-FE	U.S. Department of Energy, Assistant Secretary for Fossil Energy
DOE-HQ	U.S. Department of Energy, Headquarters
DOE-ID	U.S. Department of Energy, Idaho Operations Office
DOE-MD	U.S. Department of Energy, Office of Fissile Materials Disposition
DOE-NE	U.S. Department of Energy, Office of Nuclear Energy
DOE-OFE	U.S. Department of Energy, Office of Fusion Energy
DOE-OHER	U.S. Department of Energy, Office of Health and Environmental Research
DOE-ORO	U.S. Department of Energy, Oak Ridge Operations Office
DOE-PO	U.S. Department of Energy, Assistant Secretary for Policy, Planning, and Program Evaluation
DOE-RW	U.S. Department of Energy, Office of Civilian Radioactive Waste Management
DOSAR	Dosimetry Applications Research
dpa	displacements per atom
DSM	demand side management
EAS	environmental analysis support
ECAO-CIN	EPA Environmental Criteria and Assessment Office, Cincinnati
ECR	electron cyclotron resonance
EEO	equal employment opportunity
EEO/AA	equal employment opportunity/affirmative action
EGF	epidermal growth factor
EIA	Energy Information Administration
EMAP	Environmental Monitoring and Assessment Program
EMF	electric and magnetic fields
EMIC	Environmental Mutagen Information Center
ENEA	National Committee for Research and Development of Nuclear and Alternative Energy (Italy)
Energy Systems	Martin Marietta Energy Systems, Inc.

EOSDIS	Earth Observing System Data and Information System
EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
ER-LTT	Energy Research Laboratory Technology Transfer Program
ERDMP	Environmental Restoration Data Management Program
ERWM	environmental restoration and waste management
ES&H	environmental, safety, and health
FDDI	fiber distributed data interface
FEMA	Federal Emergency Management Agency
FERC	Federal Energy Regulatory Commission
FFA	Federal Facilities Agreement
FICA	Facility Interface Capability Assessment
FIS	fluoroimmunosensor
FT	Fourier transform
FTE	full-time equivalent
ftp	File Transfer Protocol
FUSRAP	Formerly Utilized Sites Remedial Action Project
FWCD	fast wave current drive
FWG	folded waveguide
FY	fiscal year
GAX	generator–absorber–heat exchanger
GCM	general circulation model
GIS	geographic information system
GLCA/ACM	Great Lakes Colleges Association/Associated Colleges of the Midwest
GM	General Motors
GPE	general-purpose equipment
GPP	general plant project
GRAIL	Gene Recognition and Analysis Internet Link
GSF	gross square feet
GT-MHR	gas turbine–modular helium reactor
GUI	graphical user interface
GWPO	Groundwater Program Office
HBCU	historically black college or university
HERMIES	Hostile Environment Robotic Machine Intelligent Experiment Series
HEU	highly enriched uranium
HFBR	High Flux Beam Reactor
HFIR	High Flux Isotope Reactor
HGMIS	Human Genome Management Information System
HPCC	High Performance Computing and Communications
HPCRC	High Performance Computing Research Center
HPRR	Health Physics Research Reactor
HRIBF	Holifield Radioactive Ion Beam Facility
HSRD	Health Sciences Research Division
HSSI	NRC Heavy-Section Steel Irradiation Program
HSST	NRC Heavy-Section Steel Technology Program
HTML	High Temperature Materials Laboratory
HVAC	heating, ventilation, and air conditioning
I&C	instrumentation and controls
ICRF	ion cyclotron range of frequencies
IDB	Integrated Data Base
IEA	International Energy Agency
IFDP	Isotope Facilities Deactivation Project
IFMIF	International Fusion Materials Irradiation Facility
IFP	Integrated Facilities Plan

ILL	Institut Laue-Langevin (Institut Max von Laue–Paul Langevin)
IMSL	Intelligent Measurement Systems Laboratory
IMTT	Information Management Task Team
INS	Institute for Neutron Studies
IPDP	Isotope Production and Distribution Program
IRM	information resource management
IRM/SP	Information Resource Management Strategic Plan
IRP	Installation Restoration Program; integrated resource planning
ISAM	Institute for the Study of Advanced Materials
ITER	International Thermonuclear Experimental Reactor
JET	Joint European Torus
LANL	Los Alamos National Laboratory
LBL	Lawrence Berkeley Laboratory
LDRD	Laboratory Directed R&D
LEU	low-enriched uranium
LLLW	low-level liquid waste
LLNL	Lawrence Livermore National Laboratory
LWR	light-water reactor
M&C	Metals and Ceramics
M&O	management and operating
MEL-FS	Multiprogram Energy Laboratories Facilities Support
METC	Morgantown Energy Technology Center
MGPF	multiprogram general-purpose facility
MHTGR	modular high-temperature gas-cooled reactor
MIME	multipurpose Internet mail extension
MIT	Massachusetts Institute of Technology
MOX	mixed-oxide
MPP	massively parallel processing
mRNA	messenger ribonucleic acid
MS&E	materials science and engineering
NAP	nuclear astrophysics
NASA	National Aeronautics and Space Administration
NCI	National Cancer Institute
NEAT	National Energy Audit
NEPA	National Environmental Policy Act
NIEHS	National Institute of Environmental Health Sciences
NIH	National Institutes of Health
NII	National Information Infrastructure
NMR	nuclear magnetic resonance
NMSS	NRC Office of Nuclear Material Safety and Safeguards
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRC	Nuclear Regulatory Commission
NRR	NRC Office of Nuclear Reactor Regulation
NSF	National Science Foundation
OCRWM	DOE Office of Civilian Radioactive Waste Management
OEHS	Office of Epidemiology and Health Surveillance
OHER	DOE Office of Health and Environmental Research
ORAM	optical random access memory
ORCHID	Oak Ridge Center for Healthcare Industry Development
ORCMT	Oak Ridge Centers for Manufacturing Technology
OREIS	Oak Ridge Environmental Information System
ORISE	Oak Ridge Institute for Science and Education
ORNL	Oak Ridge National Laboratory

ORR	Oak Ridge Research Reactor
ORSOAR	Oak Ridge Synchrotron Organization for Advanced Research
ORTRAN	Oak Ridge Transportation Technology Center
OSH	occupational safety and health
OSHA	Occupational Safety and Health Administration
OSTP	Office of Science and Technology Policy
PC	personal computer
PCA	Pool Critical Assembly
PCB	polychlorinated biphenyl
PER	Program for Ecosystem Research
PETC	Pittsburgh Energy Technology Center
PHENIX	Photon Electron New Heavy Ion Experiment
PICS	Partnership in Computational Science
PMT	Performance Measurement Team
PPPL	Princeton Plasma Physics Laboratory
PRK	phosphoribulokinase
PVM	Parallel Virtual Machine
QA	quality assurance
R&D	research and development
RADCAL	Radiation Calibration Laboratory
RAP	remedial action project
RAPIC	Remedial Action Program Information Center
RBEP	Regional Biomass Energy Program
RCRA	Resource Conservation and Recovery Act
RD&D	research, development, and demonstration
RDDT&E	research, development, demonstration, testing, and evaluation
REDC	Radiochemical Engineering Development Center
RES	NRC Office of Nuclear Regulatory Research
rf	radio frequency
RFTF	Radio Frequency Test Facility
RHIC	Relativistic Heavy Ion Collider
RIB	radioactive ion beam
RIED	radiation-induced electrical degradation
RISP	Robotics and Intelligent Systems Program
RMS	recoil mass spectrometer
RNA	ribonucleic acid
RRD	Research Reactors Division
RSIC	Radiation Shielding Information Center
Rubisco	ribulose bisphosphate carboxylase/oxygenase
S&M	surveillance and maintenance
SAS	NRC Surveillance Data Base, Analysis, and Standardization program
SCSS	Sequence Coding and Search System
SEED	Summer Educational Experience for the Disadvantaged
SEER	ORNL Office of Science Education and External Relations
SERDP	Strategic Environmental Research and Development Program
SERS	Science and Engineering Research Semester
SFMP	Surplus Facilities Management Program
SHaRE	Shared Research Equipment
SIAC	specialized information analysis center
SMACRC	Surface Modification and Characterization Research Center
SMART	Science/Math Action for Revitalized Teaching
SNL	Sandia National Laboratories
ST	Spherical Tokamak
START	Small Tight-Aspect-Ratio Tokamak

STM	scanning tunneling microscope
SURA	Southeastern Universities Research Association
SWSA	Solid Waste Storage Area
TACOM	Tank Automotive Command
Td	thioredoxin
TEXTOR	Tokamak Experiment for Technology Oriented Research
TFTR	Tokamak Fusion Test Reactor
TGF-β	transforming growth factor β
TIRC	Toxicology Information Response Center
TPX	Tokamak Physics Experiment
TQM	Total Quality Management
TSU	Tennessee State University
TTI	Technology Transfer Initiative
TVA	Tennessee Valley Authority
UMTRAP	Uranium Mill Tailings Remedial Action Project
USDA	U.S. Department of Agriculture
USTRANSCOM	U.S. Army Transportation Command
UT	The University of Tennessee
UTK	The University of Tennessee at Knoxville
UV-B	ultraviolet B
VOC	volatile organic compound
WAG	Waste Area Grouping
WDC-A	World Data Center–A for Atmospheric Trace Gases
WFO	work for others
WRP	Waste Reduction Program
WWW	World Wide Web
3-D	three-dimensional

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Photographs and Drawings

Cover photograph	ORNL-PHOTO 9305-94
4.1	ORNL-PHOTO 10672-93
4.2	ORNL-PHOTO 6160-93
Organization chart	ORNL-DWG 94M-8139R